JPRS 69404

11 July 1977

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EUROPE

TRANSLATIONS ON EASTERN EUROPE

SCIENTIFIC AFFAIRS

No. 552

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TRANSLATIONS ON EASTERN EUROPE

SCIENTIFIC AFFAIRS

No. 552

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VETERINARY COOPERATION AMONG CEMA MEMBERS

Sofia VETERINARNA SBIRKA in Bulgarian No 3, 1977 pp 3-6

[Article by Dr Ivan Bozhkov and Dr I. Ilieva: "Cooperation Among Member-Nations of CEMA in the Area of Veterinary Affairs"]

[Text] The establishment of the Council for Mutual Economic Assistance in 1949 was an important international event of an economic and political nature. Its nearly 30 years of activity fully confirms its vital necessity for the all-around development of the countries of the socialist camp, for raising the prosperity of their peoples, and for the successful building of a developed socialist society.

The veterinary services of these countries that are members of the council had a large role in the successes in the area of agriculture and the food industry. The permanent group on veterinary activity of the Commission on Agriculture of CEMA is very active in coordinating and directing the efforts of veterinary specialists in protecting the health of farm animals and humans from zoonoses.

It works out documents of standards to regulate basic veterinary profilactic measures to prevent to spread of acute and chronic infectious and parasitic diseases, to raise the health requirements and quality of animal feed products, and for the planned production of highly effective immunobiological, chemotherapeutic, and disinfectant agents.

At the Sixteenth Session of the Permanent Working Group of CEMA the Commission on Agriculture worked out and adopted "Measures for Improving the Orgnaization of the Health and Sanitation System at Large Livestock Farms", to which was added veterinary sanitation standards for the designing of facilities for livestock raising.

These norms recommend the obligatory participation of a veterinary specialist, in order to prevent infections from being brought in or taken out of the facility. On his recommendation, a given technological process can in some cases be reevaluated so as to improve it or replace it with another variant, depending on the physiological and biological traits of the animals and the obligatory requirements for preventive measures. These measures show concretely the

veterinary actions that must be carried out in the surrounding zone, the veterinary-sanitation standards for raising livestock animals and for insuring optimal parameters for a microclimate; the sanitation requirements for collecting and utilizing manure; securing the delivery and quality of fodder and water, conditions for the care of young animals; and recommendations for disinfection and insect-extermination in buildings; electrical supply and other requirements.

In working out this extremely important document, the Bulgarian working group on veterinary affairs took a most active part. The standards proposed by it for the microclimate parameters were adopted without change.

In 1973 a multilateral international agreement was signed for specialization and cooperative production of veterinary preparations in order to expand and intensify the policy of cooperation and specialization according to the Comprehensive Program for the Development of Agriculture in the CEMA member states.

This obliges the countries to guarantee production of specialized veterinary preparations according to an approved list and to satisfy the needs in quantity and on time by prior contract and advance order. Moreover, the participants in the agreement are obliged to guarantee high quality in the preparations produced and to increase the variety of these with highly effective medicines.

As a result of this specialization and cooperative production, our present needs for a number of antiparasitic preparations (Amprolplus, Hemosporodine, Hexachlorparaxilol, Tremanol) are fully assured by direct imports and imports from capitalist countries have been halted. The signing of an agreement to establish a reserve of vaccine against foot and mouth disease to be maintained in the USSR will permit rapid use in case of need by any threatened member-nation of CEMA.

After long and deep discussion and formulation, an agreement was signed in 1974 establishing consultation centers for raising the effectiveness of the work of veterinary services and scientific research institutes, and for improving the methods of diagnosis of diseases and fighting them. These will have exceptional significance for future cooperation in production of vaccines, serums, diagnosis agents, and medicines. Consultation centers were established in the USSR for foot and mouth viruses and diseases of cattle, for leptospirosis and brucellosis; in the CSSR for viruses of swine diseases and coccsidiosis; in Bulgaria for poultry diseases; in Poland for enterobacteria; in the GDR for microplasmas and in Hungary for microbacteria. The duty of these centers is that upon request of the countries they perform classification, identification, and differentiation of viruses; determine their extent and standards; provide diagnosis agents and control serums; select and supply cell series for the production of vaccines.

For 2 years a consultation center for poultry disease viruses has been functioning within our Central Scientific Research Institute for Veterinary Medicine.

As a result of the work completed by the Permanent Working Group on Veterinary Affairs, the methods for the serological study of glanders, dourine, microplasmosis and leucosis in cattle were unified and standardized. Rapid methods were developed for the diagnosis of African swine plague, for respiratory viral diseases of calves and piglets, for communicable gastroenteritis, for poultry leucosis etc.

At the suggestion of the Bulgarian group, problems of veterinary-sanitation control of fodder were included in the work plan. Unified standards were prepared for microbiological research and the evaluation of meat, bone, and fish feeds intended for livestock nutrition.

In 1975 a conference of directors of veterinary services, the chief epizoologists and heads of border veterinary services of CEMA member nations was held in the GDR. Participants attended a demonstration of action against an outbreak of foot and mouth disease under modern conditions of industrial raising of animals.

To guarantee the quality of animal products, in the main, the following were worked out; veterinary-sanitation requirements that enterprises of the meat and milk industry, and their equipment, maintenance, and exploitation operations have to live up to; the standards of veterinary service of export enterprises, the hygiene of workers and the sanitation equipment for processing slaughtered animals, standards for the storage of meat, meat products and canned goods, and transport of same. Unified principles and methods for expertise analyses of meat and meat products earmarked for export have been adopted. They cover the health condition of animals on their original farms, the veterinary-sanitation requirements of pre-slaughter inspection; the procedure for past-slaughter inspection of the carcass and organs of various types of animals, the veterinary-sanitation expertise analysis of the body and interior organs for various illnesses, the veterinary-sanitation expertise analysis of sausages, canned meat and butter and the rules for putting an inspection stamp on meat.

The expansion of trade in livestock and the industrial products of animal origin presents the constant threat of acute contagious diseases for animal husbandry. This has forced the preparation and acceptance of veterinary-sanitation standards which are applied among the CEMA member nations, for the import, export, and transit of animals, food products and materials of animal origin, the processing of fodder, and also for other products that can be carriers of infection.

The successes in the area of veterinary cooperation among the member-nations of CEMA have been great. These are the fruit of thorough research and discussions, of synthesized scientific and organizational experience in every member-nation of CEMA, of the collective wisdom and creative atmosphere created during discussions and solving of all problems in the area of veterinary affairs. But the possibilities in the field of veterinary cooperation are far from exhausted. The complex program adopted for raising to an even higher plane the multilateral cooperation among the CEMA member nations opens up new

and greater possibilities for veterinary cooperation. A number of problems exist in the field of scientific research, cooperation and specialization, administrative and legal problems and others that need to be discussed in the next few years in order to find an appropriate solution.

The expanding economic ties among the CEMA member states and the developing nations demand that there be an even deeper research effort on exotic diseases, methods for immediate diagnosis, prophylaxis and counteracting them.

Cooperation and specialization in the production of chemotherapeutic and chemoprophylactic agents should be expanded and intensified. This is especially important for those applied to the food and water of livestock raising complexes and farms on which industrial technologies are being introduced in the raising of animals.

From both the epizoological and economic aspect, it is imperative in the next few years to create the potential for the complete satisfaction of the needs of the member-nations of CEMA for vaccines against foot and mouth disease and to halt imports from and dependency upon the capitalist market.

It is necessary to solve these problems in the near future: a common scientific organization for veterinary affairs and the application of cybernetic methods in its management, planning, and prognosis, veterinary accountability and statistics, work standards for veterinary specialists, etc; solution of problems of economic effectiveness of veterinary programs and criteria for their evaluation; the basic problems of veterinary legislation, the principles and methods for combatting certain diseases under contemporary conditions.

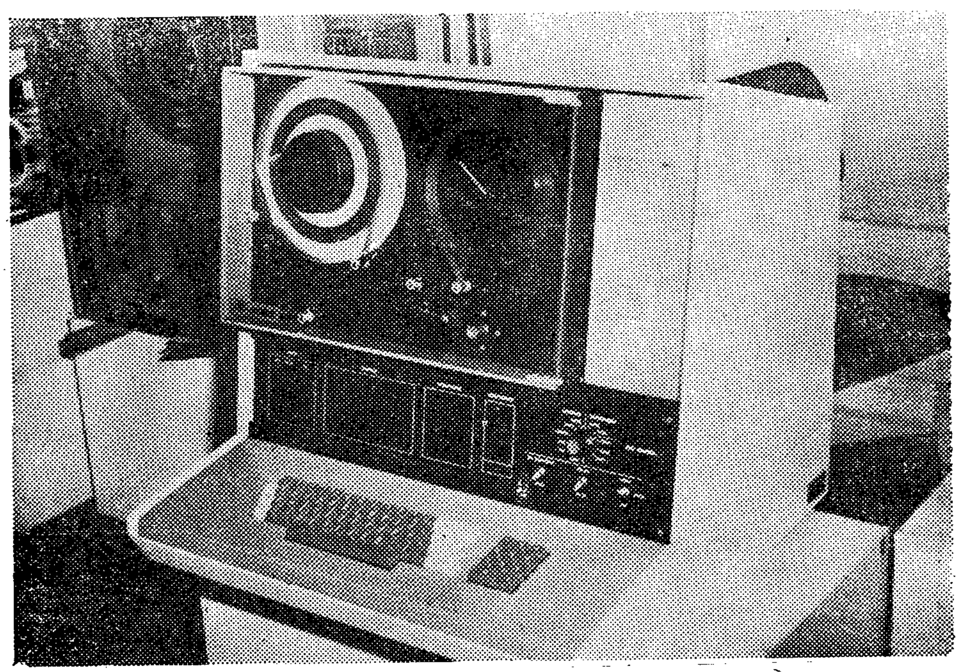
9100
CSO: 2202

ES9002 MAGNETIC-TAPE DATA PREPARATOR

Sofia RADIO, TELEVIZIYA, ELEKTRONIKA in Bulgarian Vol 26 No 1, 1977 inside back cover

[Unattributed article: "ES9002 Magnetic-Tape Data Preparator"]

[Text] The ES9002 UPDML [magnetic-tape data preparator] is intended for the direct recording of information from a keyboard on magnetic tape. It has a built-in buffer storage, which permits errors during input, noted by the operator, to be corrected at once by return of the storage address and keyboard input of the correct character.



The buffer storage is made with integrated circuits and is divided into three sections: one for data and two for programs. At a given moment operation is possible with only one of the programs in the buffer storage.

The contents of the buffer storage are not destroyed during the recording cycle. Data are preserved for checking, which is accomplished by direct reading of the recorded information block, and data read from the tape are compared bit by bit with the data stored in the memory.

While working with the unit, the operator can monitor on the display panel the memory location in which a character will be inputted, the written-in character, the program controlling storage access, and the remaining display showing the state of the unit and the operating modes.

Basic Specifications

Recording density	32 bit/mm
Recording method	NRZ-1
Rate of movement of magnetic tape	39.6 cm/sec
Buffer-storage capacity	200 bytes
Length of recorded block	80 and 160 bytes
Recording format	meets ISO [International Standardization Organization] requirements
Basic operating modes	data input, checking and retrieval
Additional modes	program input and checking; checking, input and reading by/or in the buffer storage
Programs	two independent programs
Display	sign display
Automatic functions	card reproduction; jump; arrangement by digital configuration
Dimensions	640x584x582 mm
Mass	66 kg
Power supply	220 V

The preparator was developed at the Institute of Computer Technology in Sofia and put into production at the Storage Unit Plant in Plovdiv.

6474
CSO: 2202

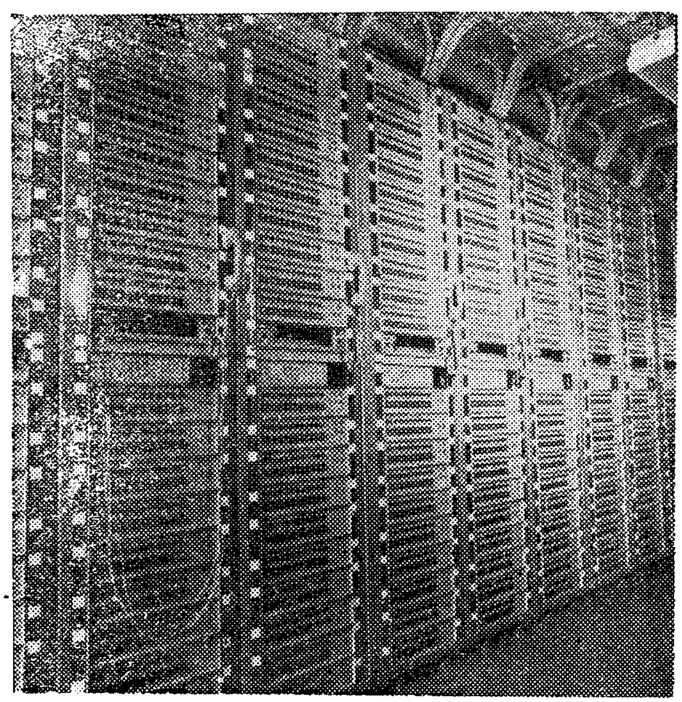
BULGARIA

COMPACT TELEPHONE SYSTEMS DESCRIBED

Sofia RADIO, TELEVIZIYA, ELEKTRONIKA in Bulgarian Vol 26 No 1, 1977 outside back cover

[Unattributed article: "Compact Telephone Systems"]

[Text] The UTS [compact telephone system]-100 series includes systems for operation over symmetric and coaxial cables and over radio relay lines. The 12-channel systems K-12-N and K-12-V are intended for operation over a symmetric cable. The 300-channel systems K-300/6 and K-300/8 operate over a coaxial cable. Eighteen hundred- and 3600-channel systems can be developed on the basis of the K-300/6, and 960- and 2700-channel systems on the basis of the K-300/8. The K-960 and K-1260 systems (960 and 1260 channels respectively) operate on a coaxial cable. The R-120, R-300 and R-960 systems can be used for operation over radio relay lines.



6474
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MEMORY APPLICATION OF CHARGE-COUPLED DEVICES

Sofia RADIO, TELEVIZIYA, ELEKTRONIKA in Bulgarian Vol 26 No 2, 1977 pp 19-21

[Article by A. Atanasov, VMEI [Higher Institute of Electric Machinery], Sofia: "Application of Charge-Coupled Devices for Digital and Analog Information Storages"]

[Text] Charge-coupled devices (CCD) are developed and employed to create a number of digital, optoelectronic and analog electronic apparatuses, some of which have unique electric characteristics.

CCD-Based Semiconductor Storages

In recent years CCD-based storages have been developed and are already in series production, at present as buffer storages but with the trend also towards other areas of the memories used in electronic digital computers (external, immediate-access, zero-access). CCD-based storages have wide-range access times -- from 10^{-3} to 10^{-6} sec. These times are significantly shorter than the access time of the magnetic drums, disks and tapes used on a mass scale and are comparable with MOS-transistorized immediate-access storages.

The operation of CCD storages is based on the dynamic shift register, i.e., they will always contain elements of serial memory.

Information is inputted in binary code into the shift register -- the basic element of the storage unit. Corresponding to logic 1 is a full potential well with charges, and to logic 0, an empty well. The length of the shift register is determined by the transfer ratio. In large-capacity devices, charge loss is overcome by periodic restoration of the initial one and zero states. Continuous storage of information in such a dynamic shift register is accomplished by periodic recirculation of information charges. Moreover, such storage takes place at a low drive speed and fewer charge losses result, while the power consumed is less. To cut down access time during reading, drive speed is increased significantly.

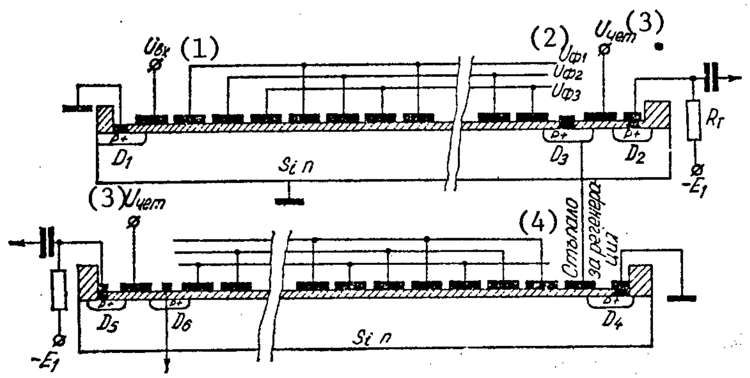

Figure 1

Key:

1. U_{input}
2. U_{filter}
3. U_{read}
4. Regeneration stage

A CCD shift register intended for a storage unit must have both an input unit for the inputting of binary information and an output unit for information read-out, as well as a unit to restore information charges to the necessary level. Two series-connected registers containing all these elements are shown in Figure 1.

To input charges not only of a discrete but also of an analog character, at the beginning of the register a diffusion region is formed (D_1 in Figure 1), overlain by a control metal electrode to which input signals are usually sent. The operation of such an input unit is analogous to the source of the gate of an MOS transistor, but here a deep depletion region, created under the first of the electrodes connected with the master clock, serves as drain. Since such a deep potential well is created periodically, the delivery of discrete signals must be synchronized with the master clock.

A second diffusion region (D_2 in Figure 1), placed at the output of the register and connected to the most negative potential E_1, is often used as an information reader. The transient charging current through this region is manifested by a corresponding drop on the resistor R_T. In front of this diffusion region a control electrode-gate is placed that gives the command for the flow of information.

Between every two series-connected registers there is a stage for the restoration of signal shape and amplitude. This is accomplished by means of a third diffusion region D_3, placed at the end of the first register.

It is not connected to a point with a certain potential -- i.e., there is a floating potential, which is determined by the potential of the depletion region situated adjacent to it. Given logic 1, i.e., given a full potential well, the potential of the diffusion region will be low and, contrariwise, given logic 0, it will be high. Diffusion region D_3 is connected electrically with the input control electrode of the next register. It can be seen that the high potential of D_3 will cause a transition of charges from input diffusion region D_4 of the second register. This means that logic 1 will be registered in the second register. In this way the signal in the second register is restored and simultaneously inverted. By connecting in series a great number of shift registers of one chip a large-capacity storage unit can be realized. This is the simplest structure of a storage unit with sequential organization.

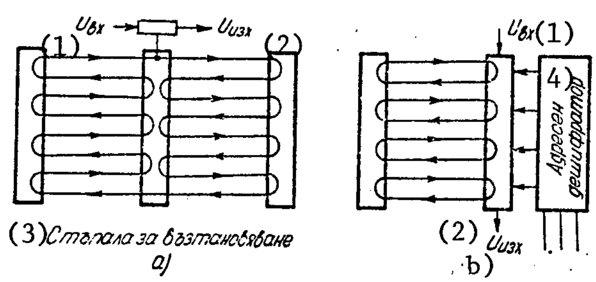

Figure 2

Key:

1. U_{input}
2. U_{output}
3. Restoration stage
4. Address decoder

Figure 2a shows the series connection of 16 registers with restoration after each of them respectively. If the registers each have a capacity of 256 bits, which is the way they have been made recently, this means that the total storage capacity is 4096 bits. The deficiency of such an organization is the great access time and the greater consumed power. In this

respect, storage units with series-parallel organization have the advantage. One of the ways of thus connecting eight registers is given in Figure 2b. Circuits of this type require an address decoder. During storage, information charges circulate at a low clock frequency (about 10-20 kHz), whereas during reading, clock frequency increases to several megahertz.

Storage units with a 16-Kbit capacity are being produced on the basis of 256-bit registers, and storage units with 1-Mbit capacity are being developed which can already be considered to rival disk storages.

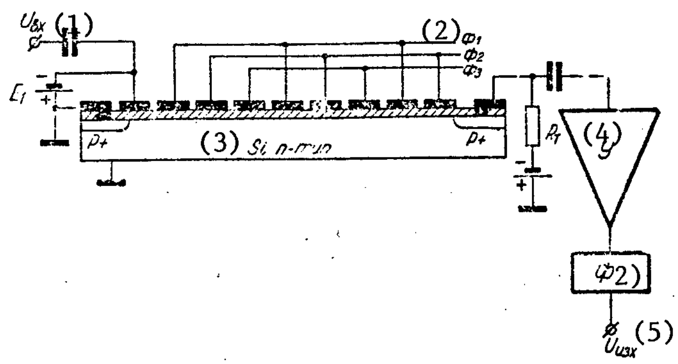

Figure 3

Key:

1. U_{input}
2. Filter
3. Si n-type
4. Expansion unknown
5. U_{output}

CCD-Analog Devices

One of the very promising areas of CCD application is electronic devices to hold, store and convert information of analog character. These include, first and foremost, electrically regulated delay lines and electronic filters.

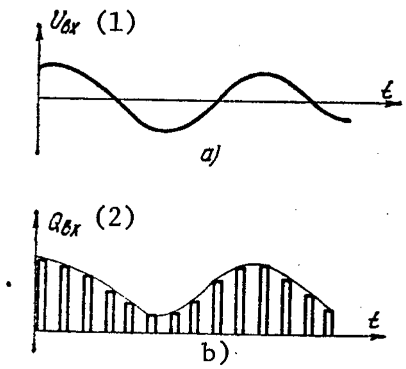

Figure 4

Key:

1. U_{input}
2. Q_{input}

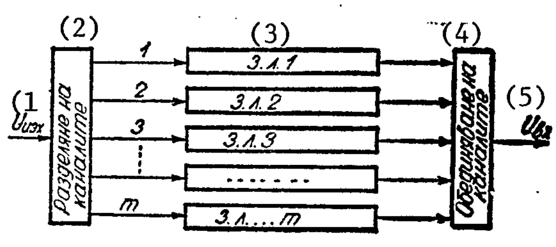

Figure 5

Key:

1. U_{output}
2. Channel separation
3. Delay line 1, 2, 3, ..., m
4. Channel combination
5. U_{input}

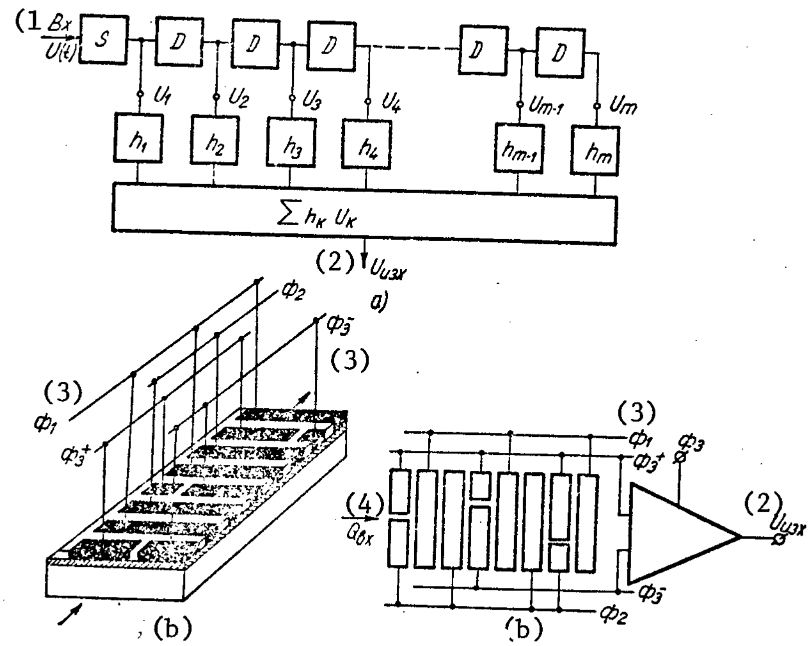

Figure 6

Key:

1. Input
2. U_{output}
3. Filter
4. Q_{input}

Delay Lines

The shift register (Figure 3), being the basis of storage units to which signals of an analog character can be sent, is also successfully used for analog delay lines. The analog signal delivered into the input (Figure 4a) is quantized automatically, and charges come to the register in the form of pulses with varying amplitude (Figure 4b). Line delay time will be directly proportional to the number of elements and inversely proportional to clock frequency:

$$t = \frac{N}{f_0} = \frac{N}{2\Delta f}.$$

According to Kotel'nikov's theorem, the maximum width of the line's frequency in most cases equals half the clock frequency. Delay time can be regulated electrically by changing the clock frequency. To be sure, the limiting value of the transfer ratio restricts obtaining very great delay times. This shortcoming is eliminated with delay lines with parallel organization (Figure 5). If the line contains m parallel registers and every one of the registers contains N elements, the total delay will be m times greater than that of the individual N-element shift register.

If more complex delay lines of this kind are used, additional channel-separation blocks are included in the input of the device, and channel-combination blocks in the output. With such lines, delays in a range of 10^{-6} to 10^{-1} sec can be realized, and what is more, electrically regulated delays.

Electric Filters

CCD filters are used to process analog signals, but are in their nature discrete. The signal entering the input is preliminarily quantized into individual discrete values.

At present, the easiest to design are so-called transverse filters, with which arbitrary pulse characteristics can be obtained. Such a filter can also be used as an analog filter, again with arbitrary characteristics in a certain frequency range.

An especially important advantage of the filters designed with CCD is that their time response can be obtained only by choosing the appropriate configuration of metal electrodes. Actually, transverse filters represent a delay line with certain, so-called weighting leads of its electrodes. Through a voltage divider or amplifier as the case may be, signals differing in phase and in amplitude, which are summed in the output unit, are picked up by different electrodes of the line. Planning such a filter requires, essentially, finding appropriate weighting factors for the prescribed pulse response.

The functional diagram of the transverse filter (Figure 6a) consists of an input unit where input analog signals are quantized and m sections of the delay line, each of which effects a signal delay which is a multiple of the clock period. A signal with appropriate weighting factors h_k is accepted from any section and delivered to the adding output device. When the weighting factors are less than unity, they are realized by dividing the electrodes of the delay line crosswise in a prescribed relationship (Figure 6b, c). This division is done during the production of the CCD and does not complicate its manufacture. The charges that pass under the divided sections and determine the summed (in respect of phase and amplitude) currents in each of the two sections are delivered to

the master differential amplifier. If the weighting factors are greater than unity, i.e., when amplification is required, there is included in each section of the delay line an MOS transistor with a certain transconductance which determines the value of the weighting factor.

The main advantage of filters containing MOS transistors on which weighting factors depend is that they can be designed to be programmed. This means that by changing the weighting factors electrically or otherwise a filter with a variable time response can be obtained. For such programmed filters one can use MOS transistors with a double dielectric, performing the role of load transistors on which the threshold voltage is varied electrically. Such filters will find application in radar, single-sideband modulation, speech scramblers and a number of other more specialized fields.

6474
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STRUCTURE AND OPERATION OF THE NUCLEAR POWER PLANT

Sofia ENERGETIKA in Bulgarian Nos 8-9, Aug-Sep 76 pp 5-11

[Article by Engineer Kozma Kuzmanov of the Kozloduy AETs [Nuclear Power Plant]: "Structure and Operation of the AETs"]

[Text] No other technological sector has had such a fast and broad development as the atomic power industry. As the offspring of the great Soviet state, and of technical progress, for the sake of the peace and prosperity of the people, in some 20 years the nuclear power plants reached the level of technical and economic maturity reached by convential power plants after nearly 100 years of development.

The fact that for over 2 years the first two power units of the Kozloduy AETs, the pioneer of our nuclear power industry, have been in operation near the historical Kozloduy is a matter of honor and pride for our country.

At this stage the first Bulgarian nuclear power plant is being built with four power units of 440 MW each, two of which are already in regular use while the two others have reached the intensive building stage. Since the first parallel flow with the power system, on 24 July 1974, the Kozloduy AETs has produced over 7.0 billion kWh electric power; nearly 3.0 billion kWh were produced this year alone, or about 20 percent of the overall Bulgarian electric power production. Obviously, both in terms of output and installed capacity the power plant occupies an important position in the country's power system and, since some substantial differences separate it from power plants using organic fuel, it has triggered the natural interest of every power specialist concerning its structure and operational systems.

1. Description of the Technological System of the Kozloduy AETs

The Kozloduy AETs is equipped with water-cooled power reactors under pressure (VVER), widely used in the past few years. AETs using such reactors have become standard in the Soviet Union and are becoming standard both in our country and in the remaining socialist countries.

The Kozloduy AETs has a two-circuit system in the "double unit" variant. In other words, each power unit consists of a reactor and two turbogenerators connected to the power system as a unit through a transformer and an electric power distribution system.

First Circuit

The main purpose of the first circuit which is radioactive is to take the released heat from the active reactor zone or the chain reaction zone (Fig 2, 12) and transfer it to the second circuit through the steam generators (PG) (Fig 1, 11). The first circuit includes the reactor with a 1,375-MW thermal capacity and six circulation circuits. Each circulation circuit consists of a collarless single-stage centrifugal main circulating water pump (GTsP) (Fig 1, 8) with a built-in electric motor; a surface-type steam generator with a 542 tons/hr productivity and a 2,510-m^2 heat exchange surface, stainless steel pipes ("cold" and "hot" line) 560 x 32 mm in dimension, connecting the reactor, the GTsP, and the PG; and main electric powered shutoff 500 mm nominal diameter valves.

The existence of a block fixture makes it possible to isolate a given circuit in case of damage and the need to repair some of its components merely by reducing the reactor's power without stopping it.

Desalinized water containing a certain amount of boric acid is used as coolant and neutron moderator.

A constant pressure of 12.5 MPa (125 atm) is maintained in the circuit with the help of a system for the compensation of temperature variations in the coolant. The basic element in this system is the steam volume compensator (KO) (Fig 1, 6), connected with the "hot" and "cold" pipes of one of the circuits in the nondisengagable part of the circuit through two 200-mm nominal diameter pipes. The full volume of the KO is 38 m^3 and the effective pressure is 12.5 MPa. A steam cushion forms over the surface of the water in the KO under working conditions. The pressure is created through electric heaters built in in the lower part of the KO. They are automatically regulated with a controller which controls the pressure in the circuit. Should the average temperature of the coolant change in the transient conditions some of it shifts from the KO to the circuit or back and the effective pressure is maintained as a result of the contraction and expansion of the steam cushion. The KO water volume also participates in the compensation process. When the steam expands some of the water evaporates while when the steam contracts it condenses.

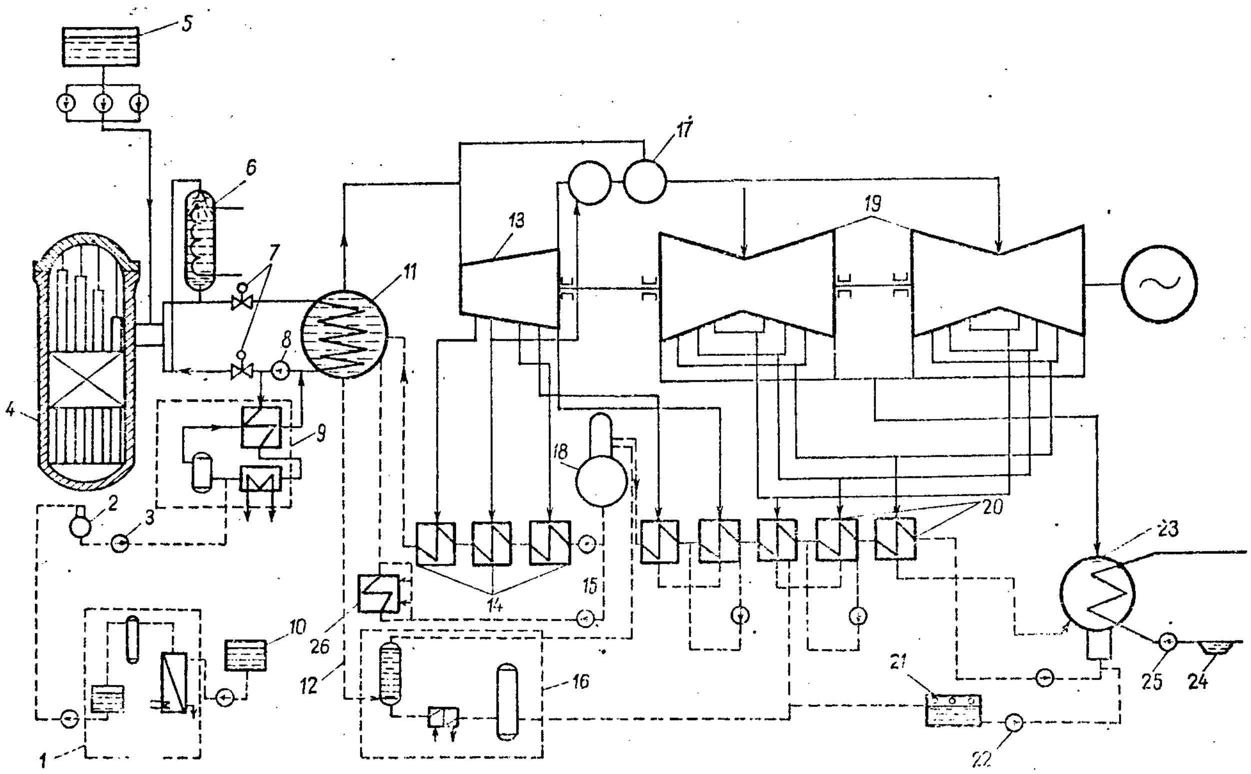

Figure 1. Basic AETs Thermal Circuit

Key:

1. Chemical water purification
2. Feed water deaerator
3. Feed water pump
4. Reactor
5. Boron intake system
6. Volume compensator
7. Main actuating electric powered valves
8. Main circulation pump
9. Special water purification
10. Untreated water tank
11. Steam generator
12. Steam generators blowing
13. High pressure cylinder-turbine
14. High pressure heaters
15. Feed pump
16. Steam generators blowing
17. Steam superheater
18. Deaerator
19. Low pressure cylinder-turbine
20. Low pressure heaters
21. Drainage tank
22. Drainage pump
23. Condenser
24. Cold canal
25. Circulation pump
26. Heat exchanger

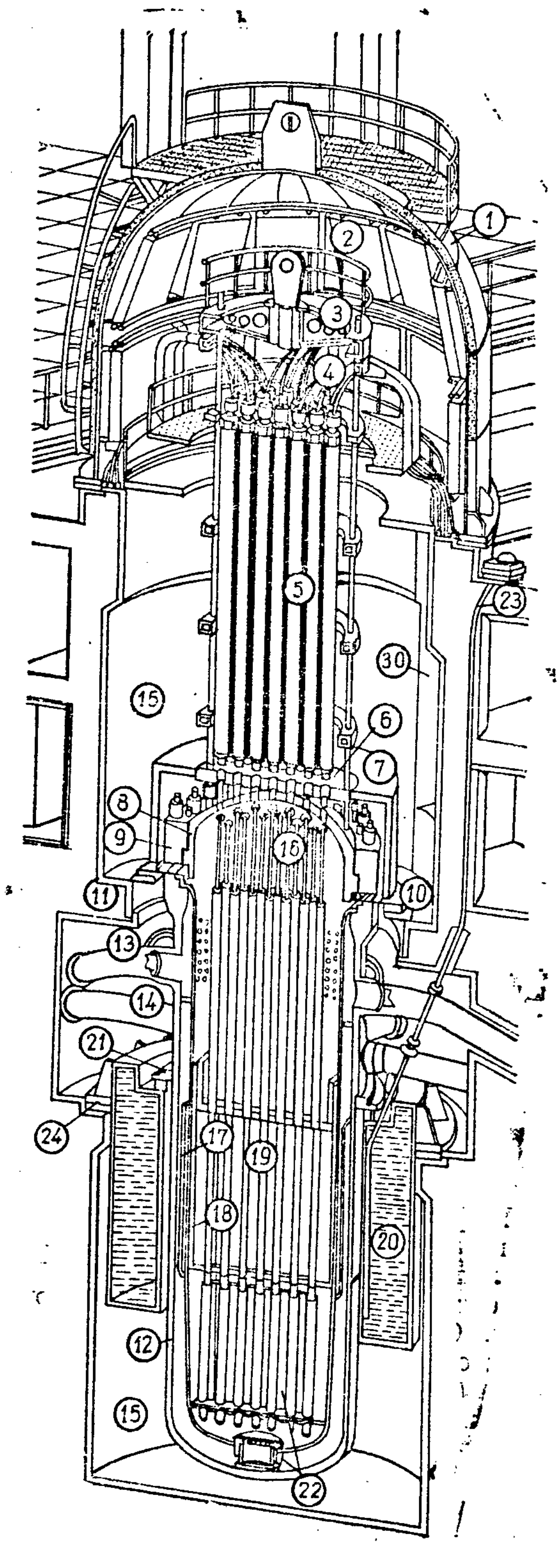

Figure 2. VVER-440 Reactor

Key:

1. Protective hood
2. Hood cooler
3. Cross-piece for moving the upper unit
4. Power cable layout
5. Protective pipes for activating the safety fuel assembly
6. Reactor hood thermal insulation
7. Removable thermal insulation above the reactor
8. Spherical reactor hood
9. Clamping ring
10. Bellows-type sealing
11. Concrete bracket
12. Reactor housing
13. Outgoing nozzle
14. Intake nozzle
15. Reactor pit
16. Drive rods
17. Protective screen
18. Removable "basket"
19. Active section assemblies
20. Protective annular reservoir
21. Support ring of the reactor's housing
22. Shielding pipes for fuel assembly bellows-type sealing
23. Ionizing chamber channels
24. Protective reservoir support ring

The purification system of the first circuit (Fig 1, 9) keeps the qualities of the coolant within the limits of the stipulated norms of a normal water-chemical system. The water may be fed by any of the "cold" lines of a given circulation circuit, is systematically cooled in a countercurrent regenerative heat exchanger and after-cooler to a temperature of 50°C, and enters the ion exchange filters (anionite, cationite and one mixed action) for the removal of corrosion and decay products. The purified water is warmed up in the regenerative heat exchanger and fed back to the first circuit on the suction side of the GTsP. The system's output is 20 m^3/hr.

The purpose of the first circuit supplementing system is to compensate for leakages and regulate the boric acid concentration in the circuit. The system consists of an atmosphere-type deaerator (Fig 1, 2) and of three piston pumps each of which has a 6 m^3/hr output.

There are two types of circuit leakages: organized and unorganized. The leakages from the collars and flanged joints of the GZZ, the leakage chamber of the PG and the GTsP, the KO hatch seal, and the main flanged joint of the reactor are organized. The unorganized leakages are those of the remaining installations and deactivation waters. They collect in small pits located in all the premises of the reactor's section, from where they flow into a special-purpose sewer system and, through a system of reservoirs (Fig 1, 10), to the special water purification system No 3 (Fig 1, 1). Due to the fact that the unorganized leaks have a high content of salts and organic admixtures, the purification system is equipped with evaporation apparatus and mechanical filters with whose help the polluted water of the unorganized leaks is processed to pure condensate for recirculation in the circuit.

The organized leaks, flowing into a common collector, are cooled in a heat exchanger, treated in the special water purification system No 2, consisting of a mechanical, anionite, and cationite filter, and, through a resevoir (Fig 1, 10) and special water purification system No 3, are fed as pure condensate for recirculation.

Cases of breakdown leaks of the first circuit coolant must be compensated promptly through the standby boron supply system (Fig 1, 5) which includes a reservoir for boron solution and pumps for feeding it into the circuit.

The first circuit systems are located in the reactor section of the main housing. The reactor itself (Fig 2) is located in the center of the reactor section, in a concrete pit. The steam generators, GTsP, pipes, and armatures are located around the pit in special boxes. The shielding from the powerful stream of ionizing radiation consists of an annular reservoir (Fig 2, 10), filled with water, and an annular reinforced concrete structure, 1.5 m thick and with a 3.6-tons/m^3 concrete density.

Second Circuit

The characteristic feature of the second circuit of nuclear power plants of the Kozloduy type is the production and utilization of saturated steam free from radioactive pollution. The six steam generators generate about 2,700 tons/hr of dry saturated steam with a 4.7-MPa (47 atm) pressure which is fed to the turbines along the main steam pipes.

The technological system of the second circuit, which is essentially that of a turbine shop, resembles the system of turbine shops in conventional thermoelectric power plants. The main differences are based on the existence of the first circuit cooling system and the fact that saturated steam is used.

The K220/44 turbines (i.e., with a nominal power of 220 MW and a 4.4-MPa (44 atm) steam pressure at the entrance are of the three-cylinder one-spindle type with one high pressure cylinder (TsVN (Fig 1, 13) and two double-flow low pressure cylinders (TsNN) (Fig 1, 19). Since after the TsVN the steam's moisture may reach 10-12 percent, two steam superheater-separators (SPP) (Fig 1, 17) have been placed between the TsVN and the TsNN, in which the moist steam is dried, warmed up, and fed to the TsNN.

For regeneration purposes the turbines are equipped with eight unregulated steam discharges each. The regeneration system itself consists of five low pressure superheaters (PNN) (Fig 1, 14) and three high pressure superheaters (PNV). In the PNN the condensate is heated to 150°C and, passing through the deaerators, out of which the feed water emerges with a temperature of about 160-180°C, is fed to the PNV through four operating and one emergency pump per power unit, where it is further heated to 220°C. The suction and pressure pipes of the feed pumps are interlinked, as a result of which any given pump, including the emergency one, may be used for feeding water to the PNV, to any unit turbine. Two emergency feed pumps (Fig 1, 15) which supply water directly from the deaerator to the PG, have been installed for use against any eventual draining of the steam generators should the plant's personal supply system break down.

In order to maintain a minimum of 96 percent vacuum in the turbine condenser an average of 33,000 m^3/hr of cooling water with a rated 12°C water temperature passes through the condenser, fed by two circulation pumps (Fig 1, 25). This is the prerequisite which also determines the maximal rated capacity of 440 MW/power unit.

The cooling of the first circuit is achieved by taking the steam from the PG through the cooling reduction system (RUR) which has a 60-tons/hr capacity. From the RUR the steam is fed consecutively to the technological condenser and the cooler (Fig 1, 26), from which it goes to the deaerators and, from there, to the suction main of the feed pump.

The blowing of the steam generators along the second circuit is needed in order to keep the salt content of the feed water within the admissible levels. As a rule, the blowing water has no radioactive pollution. It may become active only if the sealing of the steam generator pipes is disturbed, as a result of which, for safety purposes, the water is cleaned in the special water purifier No 5 (Fig 1, 10) which includes heat exchange equipment and ion exchange filters. The purified water is fed into the draining tanks (Fig 1, 21) of the machine room for use by the second cycle circuit.

Production Process Water Supply

The production process water supply of the Kozloduy AETs includes the circulation water supply system and two systems for industrial water supply to principal and secondary consumers. It is based on a two-step Danube River system: The first step is a shore pumping station which raises the water from the Danube River to the "cold" feed canal (Fig 1, 24) along which it is fed to the second step--the circulation pumping station located in the immediate vicinity of the turbine room. From here the water is fed through a unit system for cooling the condensers and serving the other industrial water consumers.

The industrial water supply to main consumers is achieved with the help of industrial water pumps installed in the circulation pumping station. The main system here is that of heat exchangers in the intermediary circuits for cooling the stators of the GTsP motors and the power actuating of the SUZ.

The purpose of the intermediary circuits is to reduce to a minimum the possibility that water from the first circuit may seep into the process water, for which reason the water pressure in the intermediary circuits is always kept below that of the process water. The water of the intermediary circuit either consists of pure condensate or is desalinized. It is replaced entirely in the case of radioactive pollution.

The process water supply system for secondary consumers supplies water to the remaining plant systems and equipment which are not involved in the elimination of breakdowns.

Electric Power Section

The Kozloduy AETs is part of the country's power system. The electric power is carried out with three 220 kV and three 110 kV power cables The four generators with a 220-MW capacity each and a 15.75-kV stator winding tension are connected with the 220-kV ORU [outdoor distribution system] through 250 MVA step-up transformers.

A house supply generator with a 6-MW capacity and 6-kV tension has been installed at one of the spindles of the main generator. It supplies the power needed by the GTsP. The main exciter is a high frequency induction-type generator also placed on the same spindle with the generator.

In addition to the house supply generators, the plant's house supplies are also met through branches of the generator outlets with the help of 15/6/6 kV, 25 MVA transformers. Emergency house supplies are provided by one 110/6/6 kV, 32 MVA transformer and one 220/6/6 kV, 32 MVA auto-transformer.

The house supply consumers may be classified into three groups:

Group 1: allow short interruption;

Group 2: allow 3-minute interruption but mandatorily require connection following the interruption;

Group 3: consumers with no particular requirements for secured electric power supply.

Based on nuclear safety conditions the electric power supply of the GTsP comes from three independent sources, two GTsP each per house supplies generator and one through transformers attached to each main generator. Such a power supply system excludes the simultaneous dropout of more than two GTsP whatever breakdown may occur at the power plant or in the case of an interrupted connection with the electric power system.

Power supplies to second group consumers come from six diesel generator groups (three/unit), each with a 1,600-kW capacity and 6-kV tension.

The direct current consumers using a 220-V tension are supplied with the help of two unit storage batteries and one unit back-up plant storage battery.

Reactor Control and Shielding System

The reactor is controlled by introduction or removal from the active zone of the neutron-absorbing material. Thirty-seven removable rods of the reactor control and shielding system (SUZ), evenly distributed in the active zone, are used to compensate for reactivity changes in the operation and for controlling the capacity and breaking the fission chain reaction. The rods consist of an upper section which absorbs the neutrons and a lower combustion section. In addition to the movable SUZ rods, the reactor's reactivity is controlled through the concentration of boric acid in the first circuit coolant.

The first and second circuit parameters are controlled from a unit control shield in which all measurement instruments and the mimic diagram showing the condition of the equipment are mounted. The Soviet IV-500 computer is used for the fast and accurate data gathering, processing, and retrieval. The coordination between turbine and reactor capacity is achieved through an automatic controller (which is a small specialized electronic machine) whose impulse is based on the amount of pressure in the main steam collector.

2. Kozloduy AETs Basic Operational Systems

The technological level of nuclear electric power plants at the present stage and the technical conditions governing the work of the equipment and the nuclear fuel do not allow drastic, major, and frequent load changes. For these reasons, like nuclear power plants in other countries, the Kozloduy AETs operates within our electric power system under basic operations conditions. Load changes and unit stoppages are determined by the need for planned-preventive equipment repairs and the need to replace the spent fuel. Under such circumstances the following basic operations systems are possible:

Switching on and loading;

Work with load;

Planned stopping and disengaging of the circulation cycle;

Reactor reloading.

Work With Load

Under this system or operating "at capacity" the unit may operate at nominal capacity with both turbines with different turbine loads, or with a single turbine. The most advantageous and economical system is the nominal in which the six circulation circuits are in operation, and the main steam conduits of the steam generators and all necessary first and second circuit auxiliary systems are parallel connected.

Should the basic systems of the first circuit or the turbogenerator be damaged the reactor may operate with a reduced number of circuits (no less that four) which makes it possible to save on electric power for house supplies. In such cases it would be expedient for the inoperative circuits to be kept under pressure or warmed up with second circuit steam generators filled to the normal level, connected with the operating steam generators through the main steam conduits. The thermal capacity of the reactor and the electric capacity of the one or two working turbogenerators are determined by the number of circuits which have remained operative and the electric supply system of the GTsP (in this case the capacity is based on the number of GTsP supplied by the house supplies generator).

The so-called "capacity effect" system may be classified in this category. This is a system developed when the fuel reactiveness stock has been used up and when as a result of the negative capacity and temperature reactiveness coefficient of the VVER-type reactors the work is being done with a steadily decreasing unit capacity with no possibility to change it. The use of this work method depends mainly on the requirements and regimen of the electric power system and is applied if economically substantiated (the possibilities governing its eventual application in our country are as yet to be studied).

Planned Stoppage and Disengagement of a Circulation Circuit

Stopping the power unit is related to planned-preventive repairs or reactor reloading, whenever the fuel reactiveness reserve has been reduced to zero. The operation is conducted in the following technological order:

1. The load of the turbogenerators is reduced to zero and they are systematically parallel disconnected, in the course of which all first and second circuit auxiliary systems are in operation while the steam generators are fed by the main feed pumps. While unloading the necessary temperature difference is maintained (no less than 40°C) in the general part of the first circuit and the volume compensator by periodically connecting and disconnecting the volume compensator heaters; when the load is reduced by 25 percent one GTsP is disconnected; with a 50 percent reduction, two are disconnected. With a 25-MW electric load of each of the turbogenerators the feeding of the GTsP is transferred from the house supplies generators to the back-up transformer.

2. The reactor is stopped (or, in the language of the physicists, is "dampened") by dropping all control rods to the extreme lower position.

3. The first circuit is cooled off using the water-steam system to a temperature of 180°C.

Three other GTsP are disconnected in 20-minute intervals. The last continues to operate for yet another 5 to 10 minutes and is disconnected with fully opened GZZ in order to maintain a natural circulation of the coolant through the active section (all GZZ are opened at a 200°C temperature). The full cooling system goes through the steam generators, the RUR, TK, and OTK, from which the condensate enters the deaerator at a 50°C temperature and then, through the back-up feed pumps, rejoins the steam generators. The temperature disparity between the "cold" and "hot" line is maintained at about 30°C. The cooling process is automatically controlled by lowering the temperature at a constant speed of 30°C/hr along with lowering the circuit pressure. This is done by injecting additional water in the KO in accordance with a program which helps to maintain the temperature difference between the KO and the "hot" line.

4. Cooling off the first circuit according to the water cooling system to a temperature of 50-60°C.

All steam generators on the side of the main steam collector are disconnected when the temperature of the coolant is about 180°C and of the water in the deaerator, 100°C, with the exception of one used in the cooling-off procedure. The steam generator, steam conduit, and part of the main steam collector leading to the RUR and the TK are slowly filled with feed water, with which the circuit is closed with the steam generator through the cooling pumps. This way the temperature in the first circuit is lowered to 50-60°C at which point it is considered that the cooling has been accomplished. Along with the lowering of the temperature the boric acid concentration is raised aimed at the "deep dampening" of the reactor and insuring nuclear safety conditions.

5. The circulation circuit is disconnected.

The work of the unit with a partial number of circuits becomes necessary in the event of misses in isolated sectors of circuits or steam generators, or damages to the GTsP. The unit load is lowered in accordance with the number of operating circuits. This is followed by closing the GZZ of the "cold" line, disconnecting the GTsP and closing the operating gear of the steam and feed sides of the steam generator on the side of the second circuit. We then undertake to cool off the circuit which is done in accordance with a system similar to that of cooling off a reactor for stopping it. The draining is done with a cooled-off circuit, following the system of organized leakages.

Reloading

Reloading is an annual operation in which we replace the spent fuel to the amount of one-third of the full loading volume of the active section of the reactor. We must note that one of the basic operational tasks is to insure the maximal combustion of the fuel which largely determines the economic running of the plant. Reloading is a responsible process whose preparations and implementation demand high technical competence, impeccable organization, and high conscientiousness on the part of the personnel.

Long before stopping the reactor the reloading and network schedules of the operations are elaborated and each item of the schedule is backed by individual programs.

After the reactor has been stopped we undertake the cleaning or, as it is usually described, the deactivating of the circuit from radioactive elements. This is accomplished through a repeated water replacement in the first circuit with the simultaneous blowing of released gases. In order to insure a profound subcriticality of the active section the boric acid concentration is raised to 12 g/1 both in the circuit and in the basin where the fresh and spent fuel is kept.

The reloading operation itself is done automatically by the "reloading machine" which is equipped with an industrial television system. The fuel remaining in the reactor is checked for the sealing of the heat transfer elements using a special method with a system installed in the vicinity of the reactor.

After completing the reloading operation we lock the reactor and complete the measures for checking the first and second circuit systems on the entire unit which, in fact, represents the connecting of the reactor and the unit.

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PROCESS CONTROL AND AUTOMATION AT KOZLODUY PLANT

Sofia ENERGETIKA in Bulgarian Nos 8-9, Aug-Sep 76 pp 21-25

[Article by Engineer Nanyu Vaptsarov, Kozloduy AETs [Nuclear Power Plant]: "Control and Automation of Technological Processes at Kozloduy AETs"]

[Text] The automation of processes in nuclear power plants has reached a very high level. This basic situation prevails at the Kozloduy AETs as well. This is demanded by a number of conditions characteristic of the technology of electric power production with nuclear fuel such as the requirement of maintaining high level safety in the work of the equipment, the possibility of radioactive pollution, the impossibility of direct access to basic installations, the high speed of the processes, the broad range of power changes, and so on. Furthermore, automation must insure the normal work of all the equipment whatever the work system of the power unit.

The following principles were observed in designing the systems for the control, automation, and administration of technological processes at the Kozloduy AETs:

The unit control panal (BShtU) is the main control center;

The auxiliary processes in the reactor systems are controlled from the instruments section panal (ShtAO);

Preparatory operations for activating or stopping the unit without the reactor part are controlled on the spot or with the help of local panals.

Centralized control is provided with a file computer (IIM). The most important measurements are duplicated with individual instruments. The IIM also computes the basic technical-economic indicators of the unit.

The present article describes in their most general aspect the systems for technological control, signaling, remote fittings and automatic regulating control, and basic shields and blockings.

Heat Engineering Control

The heat engineering control at the Kozloduy AETs is based on the following principles:

Basic parameters characterizing and securing the normal technological process, reactor system safety, unit stopping and activating, controlled from the unit control panel and the instruments section panel and the file computer which processes incoming data in analog and digital aspects, and individual analog instruments.

Operative parameters for the technological processes are controlled by multiple-point instruments or, partially, the file computer.

Auxiliary parameters, characterizing the condition of the equipment or secondary processes, are controlled with the help of multirange instruments as "requested" by the file computer.

Individual instruments have been installed for the parameters controlled through local panels or on the spot.

Parameters controlled by the file computer of the instruments section panel may be induced digitally on the unit control panel.

The following are controlled for each unit: temperature changes through temperature measurements in 1,640 points, and outlay, level, and pressure at 2,150 measurement points. Furthermore, there are 46 points for special measurements (salinometers, hydrogen ion indicators, hygrometers, and others).

The main temperature indicators are thermocouples of the following types: TKhK-551, TKhK-0675, TKhKP-0551, and TKhK-0705, as well as thermistors of the following types: TSP-5071, TSP-175, TSP-5076, and TSP-419, and so on. Spot temperatures are taken with glass mercury thermometers and TPP-SK expansion thermometers. The secondary instruments for the thermocouples are KSP and PPR automatic potentiometers; KSM and MPR automatic balanced bridges are used for the thermistors.

Levels and outlays are measured with DM differential manometers modified types 3573 and 3574 operating together with secondary instruments of the DPR, DSRM and VMD instruments. Remote control pressure measurements are taken with MED-2364 and MED-2365 sets together with DPR, DSMR, and VMD. Locally the pressure is measured with OBM, EKM, and MP gauge manometers; levels and expenditures are measured with differential gauge and alarm manometers of the DSS and DSP type. Levels at some measurement points are measured with EIU capacitance level gauges.

The instruments for special measurements are quite varied in terms of type and use. Essentially they consist of SE-12 and SE-13 salinometers, TP-1116 and TP-1120 water gauges, AK-II oxygen indicators, and others.

The impulsive lines of all measurement points in a radioactive environment are equipped with special cutoff systems which disconnect a given line should it break. The gauges are combined within several sealed premises which makes it possible to localize any eventual radiation damage. The armature is of the bellows sealing type in order to prevent leaks from it to the impulsive lines. An inverse blowing with clean water toward the higher pressure measurement point has been planned for reducing the radioactive pollution of impulsive lines and gauges.

Signaling System

In order to relieve the operator from the tiring control of parameters and the condition of the fittings, the unit control panel and the instruments section panel have a flash and sound signaling system. The sound signaling system releases different sounds depending on the importance of the change in the respective parameter.

The following signals may be given: warning and breakdown showing a deviation from technological parameters; for activating emergency shields; or for indicating the position of the blocking and controlling fixtures.

In breakdown conditions, along with the breakdown protection signal, a number of other signals are given showing deviations from the norms of one or another parameter. In such a case the parameter deviation signal which has triggered the breakdown protection is indicated by a blinking light while the other signals are indicated with a permanent light.

The signaling systems are provided mainly by units of the YaSM type and TKLM and TSS-66 light panels and RU-21 blinkers.

Breakdown Shielding and Blocking

The purpose of the breakdown shielding and blocking system is to automatically cut off the equipment and blocking fixtures depending on the development of the technological processes, and the automatic cutoff of installations and even the full disengagement of the unit in the case of breakdown.

The breakdown shielding (AZ) system delivers a control signal which informs the reactor control authorities of a deviation from the norms of the heat engineering parameters caused by a breakdown or in the case that the work of the system itself is disturbed. The breakdown shielding impulse is based on the "two out of three" system. The temperature increase impulse of the coolant at the exit of the active reactor section is the exception. It is based on the "three out of six" system.

The "two out of three" system is quite simple. At the same time, however, it is distinguished by its high level of safety and practically excludes any false activation. At the same time, it makes it possible to check in an operating reactor the good condition of the breakdown shielding equipment near the outlets.

The shielding system includes three groups of instruments. The multiplication of their signal contacts is achieved, correspondingly, with three groups of auxiliary relays. The outlets of the group relays are led to two sets of common auxiliary relays. The outlets of the common relays related to a given type of shielding (AZ first order, AZ second order, AZ third order, and AZ fourth order) are consecutively connected and led to the reactor control and shielding system (SUZ). This way the activating of a common auxiliary relay activates the breakdown shielding of the respective order.

The turbine breakdown shielding system gives a breakdown signal which activates the electromagnets of the shielding systems. The principle is the same as that of the reactor's breakdown shielding.

In addition to the breakdown shieldings of the reactor and the turbines, a number of other equipment shields have been installed. All of them share the basic concept that the breakdown shielding is the last stage of automatic control which is activated whenever the other facilities (controllers, automatic reserve switching, blockings) have failed to correct deviations in the technological process.

The purpose of the blocking devices is to provide automatic control of the systems and fittings should the parameters of technological processes change. The signals are provided by individual instruments.

Remote Control

The remote control of the equipment can be individual or selective.

Individual control facilities have been installed for the most important fixtures and the control is accomplished through individual control keys.

Selective control is applied for less important fixtures. The number of the desired fixture is selected with the help of a keyboard and a common key is used to open or shut it.

There are 874 remote control fixtures per power unit at the Kozloduy AETs.

Automotic Control

This means automatic control of the technological parameters of the unit in operation or in breakdown situations, as well as of some activating and stopping processes. There are 74 controllers per unit. We shall consider the most interesting among them.

Reactor Capacity Controller

The automatic reactor capacity controller (ARM) regulates the following systems:

Automatic control of reactor capacity in accordance with the turbine load based on a program for maintaining constant steam pressure in the second circuit.

Reactor capacity is stabilized. In such a case the neutron reactor capacity is stabilized along the flow of the ionizing chambers. In this case the turbine load is determined by the reactor's capacity.

In the case of the emergency switch-off of the main circulation pumps (GTsP), the reactor's capacity is automatically lowered according to the number of switched-off units.

The reactor capacity controller consists of two independent channels operating on a parallel basis. The output signal of the performing mechanisms is based on the "I" logical system.

Integral Controller

The purpose of this controller is to coordinate the turbine's capacity with the heat capacity generated by the reactor. To this purpose it performs the following functions:

a. Whenever the automatic reactor capacity controller is operating according to a capacity stabilization system, the integral controller maintains the turbine's capacity on the necessary level;

b. It unloads the turbine should the reactor's capacity be restricted;

c. When the reactor breakdown shielding is activated, it unloads the turbine to a no-load condition, thus protecting the first circuit equipment from inadmissibly fast cooling.

The controller operates on the basis of a program for static pressure control in the second circuit and acts through the turbine control system. Normally the controller is switched off the turbine control system. However, should the pressure in the second circuit drop to a certain level it is automatically switched on.

Fast Reduction Cooling System for the Release of Steam in the Condenser (BROUK) and Fast Reduction System for the Release of Steam in the Atmosphere (BRUA)

In the case of the fast and significant unloading of the turbine or the emergency disengagement of one or both turbines the automatic reactor capacity control is unable to reduce the capacity with sufficient speed

because of the reactor's inertia. Under such circumstances an inadmissible pressure increase would develop in the second circuit. In such cases the BROUK helps the automatic capacity controller by initiating its fast reduction system for ejecting steam into the condenser of the turbine which has "ejected" its load. Since the ARM has a lower adjustment pressure compared with the BROUK, the ARM continues to unload the reactor as a result of which the pressure in the second circuit drops. In turn, this lowers the outlay of steam through the BROUK until it is closed down entirely. After the BROUK has been closed down the reactor's capacity is stabilized at a level consistent with the remaining load in the turbine or turbines. In the case of the total unloading of the unit the BROUK operates together with the reactor's first order AZ, i.e., until the total dampening of the reactor has been reached.

Should the BROUK be inoperative (low vacuum, lack of injection water, and others), or should the pressure in the second circuit continue to rise even though the BROUK has been activated, the BRUA--the system for the release of steam in the atmosphere--is engaged. Its pressure tuning is higher than that of the BROUK. The joint work of these systems is based on a very interesting "walking system."

Pressure Controller in the First Circuit Volume Compensator

The purpose of this controller is to maintain the permanent pressure of the steam cushion in the first circuit volume compensator. It consists of two parts: The purpose of the first is to maintain constant pressure through the digital switching of groups of electric heaters; the purpose of the second is to turn on the cold-water injection system in the volume compensator should its pressure rise.

File Computer

The IV-500 MA file computer (IIM) was designed specially for centralized control of AETs technological processes.

The information coming from the primary gauges is processed in two independent channels--analog and digital.

Functionally, the computer is divided into 3 subsystems each of which could process the data received from 480 thermocouples, thermistors, differential-transformer sensors, slide-wire resistors, and others. All in all, the 3 computer subsystems could receive data provided by 1,440 primary sources.

Through switching systems the analog channel is fed data subsequently processed in the normalization system and fed to multiple gauge instruments (PPM) for retrieval. The desired parameter is triggered from the keyboard unit on the control panel and read on one of the 10 scales of the indicating instrument.

The digital channel uses the same gauges which are bypassed according to the 8s program. The gauge signal is fed to the digital conversion system and the parameter sought by the operator is presented in digital figures on a special panel. The digital channel has been programed with the extreme values of all controlled parameters. Should they be exceeded the attention of the operator is drawn with the help of audial and flash signals on the control panels.

The digital transforming system is also the input computing system. The computer operates on the basis of a fixed program and computes 156 technical-economic indicators characterizing the unit's work.

The IIM recording systems based on a predetermined program which, however, could be amended by the operator, record the following parameters:

Computed technical-economic indicators;

Parameters which have deviated from the norm;

The most important technological parameters;

The temperature at the outlets of 216 fuel assemblies from the active section of the reactor.

Conclusion

The past 2 years of operation of the first power unit of the Kozloduy AETs has proved that the ideas on the basis of which the system for technological control and automation was designed were entirely correct.

As a whole, the system worked properly and its installations confirmed their very safe operation in all failure situations.

The servicing and upkeep of the technological control and automation system of the Kozloduy AETs are in the hands of young, enthusiastic, and knowledgable specialists. This is a guarantee for high and lasting success.

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BULGARIA

NUCLEAR POWER PLANT ELECTRICAL FEATURES DESCRIBED

Sofia ENERGETIKA in Bulgarian Nos 8-9, Aug-Sep 76 pp 25-30

[Article by Engineer Anton Rachev, Kozloduy AETs [Nuclear Power Plant]: "Control and Shielding of VVER-440 Type Nuclear Power Reactor"]

[Text] Due to the circumstance that the potential energy concentrated in power reactors is very high some AETs failures may result in serious consequences not only for the personnel and the plant's equipment but the population around the plant as well. For this reason strict measures must be taken in the course of the designing, installation, tuning, testing, and operation stages of all systems having to do with the nuclear safety of the AETs. One of the systems aimed at insuring the safe work of the reactor under all possible operational normal and emergency conditions is the control and shielding system (SUZ).

Figure 1 shows the interconnection among the SUZ, the operator, and the reactor. We can see that data on the reactor's condition is received through the sensors and respective converters and used in three ways:

For automatically maintaining a certain number of parameters within the admissible limits;

For automatic reactor shielding in breakdown situations;

For the reactor's operator who may handle manually the control and breakdown shielding systems.

1. Control System

The dynamic process of the nuclear reactor must be controlled under normal operational systems in such a way as to be maintained within certain limits.

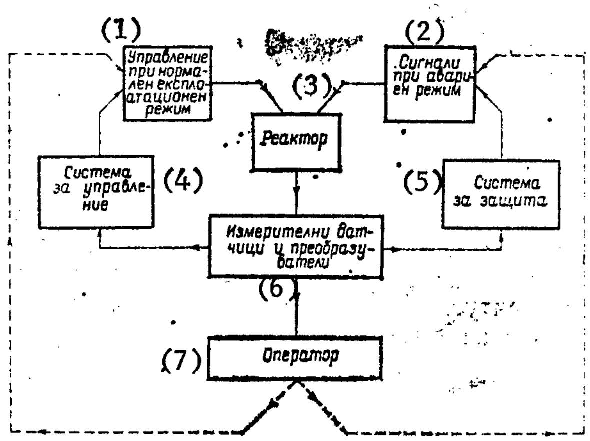

Figure 1. Interconnection Among SUZ, Operator, and Reactor

Key:

1. Control under normal working system
2. Emergency system signals
3. Reactor
4. Control system
5. Shielding system
6. Measuring sensors and converters
7. Operator

Whenever the reactor is operating at the desired capacity its fuel is bombarded by neutrons as a result of which a certain number of uranium nuclei split, thus releasing an amount of energy proportional to the number of the split nuclei. Should substances absorbing some of the neutrons be introduced somehow in the active section, the number of split uranium nuclei and, correspondingly, the capacity of the reactor, drop. This principle is the basis of the control of the VVER-440 reactor. Two types of neutron poisons are used:

Liquid poison of heat neutrons--boric acid diluted in the water of the first circuit. It is used to compensate for the slow reactivity changes such as fuel combustion and slag accumulation, and for insuring a subcritical reactor condition with a cold first circuit and in reloading the active section with fresh fuel;

Solid poison consisting of boron steel of which the absorption extensions of the control fuel assemblies are made.

The use of a liquid absorber in the new reactor types makes possible the more even distribution of the neutron flow in the active section. This means a more even distribution of the heat release and better use of the active section. The active section of the reactor consists of 312 working (fuel) and 37 control fuel assemblies. The control fuel assemblies are

divided into six groups, five of which consist of six fuel assemblies each while the sixth consists of seven fuel assemblies. Unlike the working fuel assemblies, the controlling ones have two parts--a combustion part, similar to the working fuel assemblies, and an absorbing part. With a dampened reactor all 37 absorbing parts of the controlling fuel assemblies are in the active section while the combustion assemblies are under it. When the reactor is in operation all fuel assemblies are in an extreme upper position with the exception of the fourth group which has been raised partially. This group is used to control the reactor's capacity and to compensate for fast reactivity changes.

Each of the controlling fuel assemblies has its separate electric power supply which converts the rotary movement of the power motor's rotor into the gradual shifting of the collar and the fuel assembly engaged with it along the height of the active section

The activating electric motors are synchronous, of the reactive type, and insure a constant speed (2 cm/sec) of movement of the controlling fuel assemblies, thus changing the amount of the positive reactivity introduced, and insuring the safe work of the reactor. A direct current electromagnet creates a force which couples the driving cog of the starting mechanism with the collar. When the current for the electromagnet is cut off, under the influence of a spring the cogwheel is disconnected from the collar and the controlling fuel assembly drops at a falling rate of 20-30 cm/sec to the lower extreme position. This is how the emergency dampening of the reactor is accomplished.

The system for starting the control fuel assemblies controls their starting motion, the reactor's capacity, and its slow or fast reduction in the case of emergency situations. The control may be provided by the capacity regulator automatically or achieved manually by the operator.

1.1 Manual Starting and Control of the Reactor

The unusual aspect of a nuclear reactor as a source of heat is the fact that its control begins long before it has reached its nominal capacity. The reactor reaches its critical point (i.e., a self-sustaining chain reaction is initiated within it) at a considerably lower capacity level, and the physical characteristics of the process require the control to be initiated at that level.

The reactor is started after all the necessary systems have been engaged. The control fuel assemblies, ranging from the first to the fifth group, are systematically raised to the extreme upper position, while the sixth group becomes partially submerged into the active section. The reactor is still at a subcritical point because of the high concentration of boric acid in the first circuit water. The concentration is reduced until the reactor has reached its critical condition. Should the dilution of the

boric acid of the first circuit be continued, the reactor's capacity would increase at a considerably higher speed, for which reason its control must be initiated at that very low capacity level.

After the reactor has reached the minimal controllable level (stable readings of the equipment controlling the neutron flow within the starting range), it is controlled by moving the controlling fuel assemblies of the sixth group "upwards" at a working speed of 2 cm/sec. As a result of this the capacity of the reactor begins to increase at a speed depending on the size of the positive reactivity introduced, determined both by the movement of the controlling fuel assemblies as well as the changes in the neutron flow (xenon poisoning) and the temperature effects.

The temperature of the active section may be changed by the following: introduced reactivity which changes the reactor's capacity; changes related to cooling the section; and changes in the turbine's capacity. The temperature coefficient is defined as being a reactivity change caused by a 1°C temperature change, and could be positive or negative. In the VVER-440 reactor it consists of two parts--for the moderator and the fuel. The overall temperature coefficient for capacities close to the nominal is negative. This is an important positive quality used in controlling this type reactor. A negative temperature coefficient makes the reactor self-stabilizing within a certain range. For example, an eventual rise of temperature in the active section introduces a negative reactivity which lowers the reactor's capacity and, therefore, the temperature.

Xenon poisoning also influences the reactivity introduced in the active section with any change of the neutron capacity. When the reactor's capacity is lowered the xenon decay speed is reduced and its concentration begins to rise and, since it is a strong absorber of heat neutrons, it introduces a negative reactivity. This means that in order to restore the initial capacity of the reactor additional positive reactivity must be introduced in the active section without waiting for the xenon's decay.

By moving the controlling fuel assemblies the operator gains information on the situation of each one of them through a digital position indicator indicating the location of the fuel assembly at the moment in any one of the 10 sections. Each section is 250 mm long. Selsyn indicators are used for determining precisely the position of the fuel assembly in each section. They establish the position of the fuel assembly with an accuracy of ± 2.5 mm.

1.2 Automatic Power Capacity Control

The automatic power capacity control (ARM) is used for maintaining given technological AETs parameters within the admissible range at different reactor capacity levels, ranging from 3 to 110 percent of nominal capacity, and for automatic unloading of the reactor to the admissible capacity should emergency situations arise.

Two basic ARM operational systems exist: "R"--controlling; and "SR"--"stabilization and unloading."

When the AETs operates under a controlling system the ARM insure that a given pressure level is maintained in the steam collector of the second circuit with an accuracy of ± 0.05 MP (0.5 kg/cm^2) by changing the reactor's capacity. With this system the ARM changes the unit's capacity according to the needs of the power system. For example, if at a given moment the consumption of electric power rises the moment of resistence will increase and the turbogenerator revolutions will begin to drop--the frequency of the system will decline. The speed turbine controllers which must keep their revolutions steady will open the control valves. Steam outlays will rise and thus the turbogenerator revolutions will be restored to a certain extent. The increased amount of steam going to the turbine would lower the pressure of the steam collector in the second circuit. Should it decline by over 0.05 MP, the ARM would call for increasing the reactor's capacity until the normal pressure has been reached in the second circuit. The AET's would operate at a higher capacity as a result of the increased requirements of the power system.

The inconvenience of this system is that the AETs must operate at a below-nominal capacity so that the reactor may increase its capacity should this become necessary.

In a basic AETs working system the controller operates under the "SR" system which insures a lowering of the pressure in the second circuit when the operating level is exceeded by 0.125 MR. The ARM does not react to a lowering of pressure. The lower pressure threshold is maintained by a "watching" controller which unloads the turbines by activating their control valves. Under this system the ARM can only lower the reactor's capacity. The positive aspect of this system is that the AETs may operate at 100 percent capacity.

Since the VVER-440 has a negative temperature coefficient, the reactor's capacity controls automatically, within certain limits, the capacity of the turbogenerators without the intervention of the ARM. The overall amount of heat taken out from the reactor through the coolant flowing through the steam generators is proportional to the power system load and, consequently, any increase in the AETs load is accompanied by a lowering of the coolant temperature at the entrance to the reactor. Because of the negative temperature coefficient such a lowered reactor temperature introduces a positive reactivity and an increase in the reactor's capacity, thus covering some of the additional load.

Should the load drop sharply by 50 percent (disconnection of one turbogenerator) the ARM insures the lowering of the reactor's capacity without any deviation from basic AETs parameters to the level where the emergency shielding is activated.

In the emergency disconnection of a main circulation pump (GTsP) caused by a worsening in the cooling of the active reactor section the ARM lowers the reactor's capacity by 25 percent of its value at the moment and by 50 percent when two GTsP are disengaged.

The ARM is built on the basis of the two-channel principle with automatic control of each channel and the feeding of control signals to the reactor control system through a coincidence circuit ("I" circuit). Should one of the channels break down it is automatically switched off while the other one remains operational ("ILI" circuit). This operational principle of the controller insures high reliability and lowers the probability of sounding a false signal.

Each control channel has its set of sensors. It consists of three linear channels within the energy range and two sensors showing the pressure in the steam collectors.

2. Breakdown Shielding System

Since there is no equipment which operates impeccably and since the probability always exists of a failure of the control system additional safety measures are necessary. The breakdown shielding (AZ) system controls the reactor whenever the control system has failed to fulfill its purpose and has allowed the development of a breakdown situation. Another task of the AZ is to deal with emergency situations caused by failures of other equipment or erroneous operator's actions.

The main difference between the control and breakdown shielding systems is the fact that the AZ always acts to lower a given parameter below a specific level and is engaged in the case of a considerable deviation in the required parameter. The observed parameters may be technological, such as temperature, pressure, and so on, or neutron-physical, such as capacity and period.

Control in emergency situations may be provided manually by the operator as well, bearing in mind that his actions are not relied upon.

The following question could be asked: Since there is no errorless system, what would happen should the AZ system itself breakdown at a certain point and the operator is unable to intervene on time to restore the normal process? Would this lead into an emergency situation which could have serious consequences? In order to realize why it is nearly impossible for a similar situation to develop let us consider some basic principles observed in designing the AZ for VVER-440 nuclear reactors.

The automatically operating breakdown shielding may be considered as consisting of three main parts (Fig 2): measuring channels, AZ circuit, and reactor failure system.

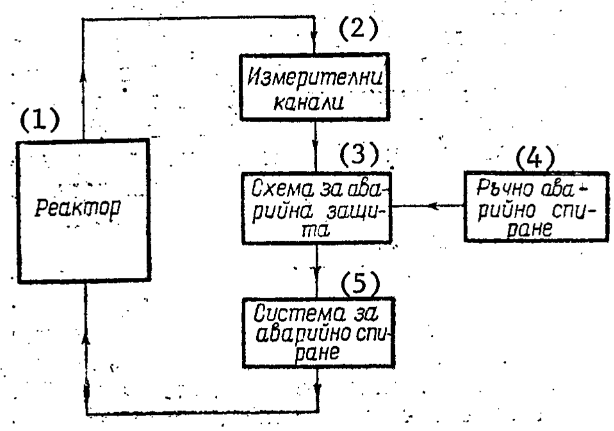

Figure 2. Breakdown Shielding Elements

Key:

1. Reactor
2. Measurement channels
3. Breakdown shielding system
4. Manual emergency stop
5. Emergency stopping system

The term measurement channel means a sensor with a converter which converts the sensor's signal into a corresponding pulse in the direction of the AZ circuits. The sensors measure different parameters such as, for example, the neutron flow, temperature, and pressure, and are located either inside or around the reactor. The system for measuring the neutron reactor flow, specific of nuclear reactors is considered an example of a measurement channel.

For each volume of the reactor's active section the neutron flow is proportional to the number of split nuclei of U^{235} and, consequently, of the energy which is released within this volume. Measuring the neutron flow gives us information on the heat capacity released in the active reactor section.

It is particularly important to measure the neutron flow in activating the reactor or in the case of rapid capacity changes.

Specific conditions prevail in the active section: high temperature and pressure and strong gamma radiation, for which reason the neutron detectors are located outside the reactor, recording the neutrons which leave it.

Two types of sensors are used in the VVER-440: proportional counters and compensated ionizing chambers. Basically the detection principle is the same for both. Whenever a charged particle is located in the space between

two metal electrodes locked in a gas-filled chamber, the gas will be ionized. In the existence of a potential disparity between the electrodes the ions will be drawn to the respective electrode and a current will flow which could be recorded. Since the neutrons have no electric charge the reaction between the heat neutron and the boron isotope B^{10} is used for ionizing:

$$_0n^1 + {}_5B^{10} \rightarrow {}_3Li^7 + {}_2He^4$$

The lithium nuclei and alpha particles are positively charged and trigger the desired ionizing. Thus the recording of the heat neutrons which have left the reactor provide us with information on the nuclear reactor's capacity. The same equipment is used to record another important value--the period T which gives us an idea of the speed at which the reactor's capacity is changing. The period indicates the number of seconds during which the reactor's capacity changes e times (2,718).

In order to perform its protective and informative functions, the equipment controlling the neutron flow should be able to register it whether the reactor has been stopped or operates at full capacity. In the case of the VVER-440 this means a heat capacity ranging from 100 W to 1,350 MW, i.e., within a seven power range. Such a range cannot be covered by a single measurement equipment for which reason three separate reciprocally backing systems are used: for the starting range, using propotional counters because of their high sensitivity, and compensating ionizing chambers for the intermediate and power ranges.

Eighteen operating measurement channels (six/range) are placed around the reactor, giving emergency or warning signals should the given levels of the neutron flow and the reactor's period be exceeded.

The reliable operation of such measurement channels could be disturbed by two types of failures: "failure with dangerous consequences," and "safe failure." The "failure with dangerous consequences" bans or delays the activating of the automatic shielding should a situation develop which would require the intervention of the AZ system. The "safe failure" prepares the AZ system for action. Should a measurement channel be damaged with "dangerous consequences," even if the reactor should be stopped, no dangerous consequences would occur since the failure of the measurement channel would block its operation, which would be inadmissible. Should the channel be subjected to a "safe failure" the reactor would be stopped unnecessarily, which would be economically unjustified.

This is avoided by duplicating the measurement channels observing the same parameter. Such a system, however, increases the possibility for an erroneous stopping. That is why in designing the AZ both conflicting requirements must be met:

The reactor must be always shielded and any failure in the AZ system must trigger its stop;

For economic considerations the false stopping of the reactor caused by failures in the AZ system must be avoided.

The "two out of three" system is a compromise between these two conflicting requirements. The AZ reactor system uses three measurement channels for the neutron flow, each of which has two outlets connected as per the diagram shown in Figure 3. Under normal operations all outlets are closed. In order for the "neutron flow" parameter to turn on the AZ the circuit must be broken. Should any one of the three measurement channels be subjected to a "safe failure" the reactor would not stop since this would require opening the contacts of at least two channels. However, should an increase in the neutron flow appear it would be recorded by the system.

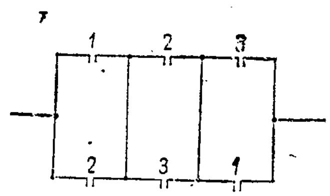

Figure 3. "Two out of Three" System

A certain inconvenience of the "two out of three" system is that if any one of the three measurement channels is undergoing repairs the system would be operating on the "two out of two" principle and would suffer from all the shortcomings we described in the case of channel duplication. That is why for each range the VVER-440 uses six measurement channels for the neutron flow forming two triads giving signals to two sets of breakdown shielding systems. In order for the reactor's AZ to be activated, it would be sufficient for two channels of the first set or two channels of the second set to become activated. This system, even though involving a large number of measurement channels, has no shortcomings both in terms of the safe work of the reactor as well as the reliability of the power plant.

2.2 Breakdown Protection System (AZ)

The purpose of the AZ system is to give a signal for dampening the reactor after receiving the signals from the measurement channels. The purpose of the design was to meet to a maximal extent the prerequisite that the elements have "safe failures." The AZ system of the VVER-440 is of the

relay type which, under normal conditions, operates under tension. This means that in normal operations the relay bobbins are powered and their contacts are closed. In order to activate the AZ we must open the contacts which is achieved by eliminating the tension, thus meeting the safety requirement. Measures have been taken for the current going through the contacts of the AZ relays to be below nominal value in order to avoid the possibility of closing them.

2.3 Reactor Emergency Stopping System

Receiving a signal from the AZ system, the purpose of the emergency stopping system is to dampen the reactor.

The breakdown shielding of the VVER-440 has four orders (or degrees of action), since not all failure situations require the full stop of the unit. For example, the first order AZ which results in the total dampening of the reactor is activated only in most serious breakdown situations. In the fourth order AZ only increasing the reactor's capacity is forbidden; in the third order AZ its capacity is reduced very slowly.

The dampening of the VVER-440 as a result of the first order AZ signal is accomplished by dipping 37 control fuel assemblies into the active section. To accomplish this we must stop the feeding of the electromagnets which power them, as a result of which the control fuel assemblies drop under their own weight at an emergency velocity of 20-30 cm/sec. The use of gravitation enables us to observe the "safe failure" principle. The additional support of the system is achieved by interrupting the current flowing through the bobbins of the electromagnets at two points in the consecutively connected contacts of the two controlling contactors.

Other measures applied in the case of all sybsystems within the AZ reactor system aimed at improving its reliability include the following:

All elements forming the AZ system are described in the course of the designing, indicating precisely the accuracy and reliability criteria they must meet;

The structural solutions exclude almost totally the possibility of a "dangerous failure;"

Transistors and integrated circuits are used instead of electronic tubes;

Shortening the interval between periodical investigations of the installations in order to detect promptly the existence of damaged elements.

The results of the work so far have indicated that the breakdown shielding system of the VVER-440 is capable of coping with all breakdown situations which have appeared. This determines the safe work of the Kozloduy AETs.

ELECTRICAL FEATURES OF NUCLEAR POWER PLANT DESCRIBED

Sofia ENERGETIKA in Bulgarian Nos 8-9, Aug-Sep 76 pp 31-34

[Article by Engineer Yordan Yotov, Kozloduy AETs [Nuclear Power Plant]: "Characteristics of the AETs Electrical System"]

[Text] With the completion of the second power unit the Kozloduy AETs became a basic unit in our power system with its two VVER-440 reactors and four 220-MW turbogenerators.

The main feature distinguishing the AETs from the conventional TETs is the prime source of energy--the nuclear reactor which has replaced the boiler of the thermoelectric power plants and which has created new previously unknown requirements related to nuclear safety. What do they consist of? Above all, of blocking activities which would disturb the working system of the active section and, respectively, of the nuclear fuel. This is the basic principle of the entire system of the nuclear electric power plant and, particularly, of its electrical system.

The main reason for violating nuclear safety is a temperature increase in the active section of the reactor reaching a temperature equal to or higher than the melting point of the shielding of heat-releasing elements. In a normal operational regimen the cooling of the active section is accomplished through the main circulation pumps--GTsP--which circulate the coolant between the reactor and the steam generator.

The GTsP are colorless 6-kV pumps with a rotor sunk in the coolant and with insulation able to withstand a temperature of up to 160°C and with special cooling systems: forced air for the front connections of the stator winding, and water for the steel and other parts of the stator winding.

The stipulations for reliable reactor work and for stable AETs operations call for a safe power supply to the electric motors of the GTsP. To this effect a supply system consisting of three independent sources electrically unconnected has been selected. The advantages of this system are the following:

The existence of four GTsP independent of the transitional regimens within the system in the case of shorts in any of its areas and, therefore, maintaining the stable work of the reactor in the case of disturbances in the EES [Electric Power System];

Excluding the possibility for a simultaneous drop-out of more than two GTsP in case of a failure in the AETs or the EES which would trigger the breakdown shielding.

Any change in the supply system which would reduce the number of GTsP fed by the house supplies generator results in a lowering of the reactor's capacity since the safety of the so-called "total de-energizing" system would be reduced. This system is one of the most important prerequisites for severe AETs breakdowns, for it is directly related to nuclear safety requirements. It occurs with the simultaneous deactivation of all working generators within the system, caused by a system failure and the closing of the shutoff valves of all operating turbines. Despite the immediate dampening of the reactor by the breakdown shielding the danger of a burn-up in the active section would be quite high if the GTsP in operation at the time of the breakdown are also turned off. Their supply in the course of 90-100 seconds from the drop of tension, i.e., for a period of time sufficient to remove the initial heat from the active section, is insured by the self-stopping of the turbo group (in practical work the Russian term "vybeg" [overrun] is used), i.e., by the kinetic energy of the rotating masses of the turbine. This shows the corelation between the reactor's capacity and the number of GTsP fed by the house supplies generators: a reduction of the possibility to cool the active section at the initial moment following the total supply cutoff. Following the self-stopping operation the residual heat release from the active section, which exists regardless of the fact that the reactor has been dampened, is removed through the natural circulation of the coolant through the first circuit.

The TVV-220-2A generators with a nominal capacity of 220 MW, a nominal tension of 15.75 kV, and a nominal current of 9,450 A and $\cos \varphi = 0.85$ are in the same unit with the 250-MVA power increase transformers.

The excitement is accomplished with the help of a high frequency exciter operating at a 500-Hz frequency through semiconductor rectifiers.

There is a main excitement reserve with the help of a spare exciter common for the four machines of the two power units. It consists of a DC 1,070-kW generator and a 6-kV 1,200-kW asynchronous motor.

Connection Between the AETs and the EES

The connection between the AETs and the EES is established when the tension reaches 220 kV. A possibility for exporting electric power exists also through the 110-kV system. The 110-kV ORU [Outdoor Distribution System] is

based on the familiar circuit of two bus and one bypass systems; the 220-kV ORU is based on the "breaker and a half" connection system which saves a certain amount of capital investments but, on the other hand, also creates certain operational difficulties.

The expansion already underway (AETs-2) calls for a 400-kV ORU.

AETs House Supplies

The AETs house supplies are characterized by stricter supply reliability. Depending on the admissible period of time during which SN [House Supplies] consumers may be kept without power, they may be classified into three categories:

One second or less--first category;

Three minutes or less--second category;

All others--third category.

Consumers using a 6-kV tension are fed by the 6-kV operating sections through operating SN transformers. The SN transformers--15.75/6/6 kV, have two secondary windings each of which feeds a separate section.

The standby power of the 6-kV section is provided by two 32-MVA transformers. The SN system includes the possibility for the parallel linking of the standby sections of the two units.

The motors not exceeding 200 kW, 380 V are fed with 6/0.4-kV, 630- and 1,000-kVA transformers with a side tension control of 6 kV.

The standby supply comes from two standby transformers, one for each unit.

The 380-V electric motors with a capacity in excess of 10 kW are connected directly to the buses of the 0.4-kV KRU [Category Distribution System] through individual lines.

Electric motors of less than 10-kW capacity and activating electric motors are fed by assemblies through automatic AP-50 and magnetic starters. The electric motor and activating assemblies receive their power from different sections with automatic activating of standby power.

Supplying 6-kV Second Category Consumers

These are consumers whose supply may be interrupted for up to 3 minutes. Independent sources have been designed for them.

In the AETs the diesel generator station is such a source.

Each diesel generator is connected to its 6-kV dependable supply section. There are two such sections per unit. The third diesel generator may be connected to either one should its respective generator be disconnected.

The diesel generators may absorb 100 percent of the load no less than 3 minutes from the time their connecting pulse has been triggered. This pulse is triggered when the tension of the respective section disappears.

The starting of the diesel generator is linked with the automatic disconnection of some of the consumers of secondary importance in order to ease the load of the diesel generator in such a situation. The sequence in which they are reconnected, after tension has been generated by the diesel generator, is based on the circuit and the automatic action of the so-called "graduated starting" which is based on the technical parameters of the diesel generator and the technological working system of the consumers.

Supplying 380/220-V Second Category Consumers

The feeding of 380/220-V 200-kW or lower capacity motors allowing a supply interruption of 3 minutes or less is accomplished by two dry 1,000-kVA capacity transformers per unit. They are supplied by the half sections to which the diesel generators are linked. Each transformer supplies a section of the 0.4-kV dependable supply KRU.

As a standby of the operating dependable supply transformers the possibility has been stipulated to supply power from the standby transformers which, should the tension drop, are fed by the diesel generator of the other unit.

380/220-V Dependable Supply System for First Category Consumers

First category consumers whose DC 380/220-V, 50-Hz supply may not be interrupted for over 1 second is provided by two dependable supply sections per unit.

Normally such sections are supplied by 1.4-kV second category dependable supply sections.

Should the tension disappear the supply of first category consumers is provided by special reversible generators (ODG) consisting of one synchronous AC and one DC machine.

The ODG has a 150-kW capacity. There are two ODG per unit. One is set on the side of the direct current. It is connected with the unit storage battery and, under normal circumstances, operates as a charging unit. The second is connected to the general plant storage battery. A standby ODG has also been provided for the two units, connected to the plant's battery.

A thyristor circuit breaker has been mounted on the 0.4-kV deviation which connects the buses of the 0.4-kV second category shield and the buses of the 0.4-kV first category shield in order to insure the work of the ODG in the case of a short circuit in the dependable supply second category sections.

220-V Direct Current Circuit

Three SK-32 storage batteries have been installed to supply DC consumers which allow short supply interruptions. Each unit has one such battery to supply consumers which back up the emergency stop of the turbines, provide constant emergency light, and feed the operative circuit breaker chains, and a plant storage battery per each two units supplying general plant consumers such as ORU, some of the emergency lights, and others. Each storage battery has its autonomous distribution DC panel.

All storage batteries supply the reactor and turbine control and shielding circuits and operate under a permanent recharging system maintaining a 240-V DC tension.

The recharging systems consist of reversible generator motors.

Each battery has standby power, i.e., standby power flowing from the unit to the plant battery and back.

In the choice of a storage battery the following is taken into consideration:

The computed duration of the interruption in the supply of AC equaling 30 minutes;

The work of the storage battery is based on permanent recharging.

In order to prevent the batteries' exhaustion and insure the safe operation of the systems, in a reduced power supply system, after switching on the diesel generators, supplies to first category consumers and storage battery recharging are transferred to the diesel generator through the 0.4-kV second category dependable supply buses and the reversible generators. The transfer is automatic.

The 380/220-V, 50-Hz power supply to power consumers comes from two independent sources along two lines from the sections to which the SN generators are connected. The handling capacity of each line insures the 100 percent load for such consumers.

The 380/220-V, 50-Hz tension for first category consumers comes from first category dependable supply buses, along two lines each which do not allow an interruption of tension in excess of 1 second. The handling capacity of each line also provides for a 100 percent load.

Admissible tension fluctuations are -12 and +10 percent of the U_t.

DC consumers using 220-V tension are also divided into two groups. Two lines each are planned for each DC consumer group with a handling capacity of 100 percent each.

Tension tolerances are -10 and +15 percent of the U_t. The capacity of the standby shielding to operate at times of interruptions or disturbances in the power supply is retained.

The description provided so far enables us to sum up briefly the characteristic features of the electric power system of the AETs compared with conventional TETs:

1. The existence of separate house supplies generators and of first category consumers such as the main circulation pumps.

2. The existence of three categories of house supplies consumers, compared with only in the TETs.

3. The existence of dependable supply systems, reversible generator motors, and diesel generators.

4. The two purposes of storages batteries: Whereas in a TETs they are used to supply only DC consumers, in the AETs, in emergency situations, the storage batteries with ODG supply AC consumers as well who cannot tolerate power supply interruptions.

5. The existence of a far greater number of automatic, relay screening, and blocking systems.

Finally, there is another feature related to the electric power system.

As we know, from the viewpoint of radiation safety and operational conditions, there are two basic operational zones in each AETs--the strict regimen zone and the clean zone.

The structure and composition of the power systems in the clean zone are not different from those of standard TETs. However, the structure and systems of electric power equipment in the strict regimen zone have a number of specific features. Above all there is an emphasis on installing a minimal amount of equipment in this zone. There are two possibilities in this case:

Concentrating the power facilities in special premises which facilitates servicing but complicates the structure of the power plant and the cable layout;

Deconcentration of electric power equipment directly in the strict control zone.

The second method is more consistent with the principle of bringing the power and control electric systems closer to the mechanisms themselves. It simplifies the structure and cable communications but increases the probability of radioactive pollution of the equipment and, therefore, makes its maintenance and exploitation more difficult.

A sensible combination of the two methods is the most acceptable one.

Such circumstances also increase the amount of remote control and guidance. This applies, above all, to the mechanisms of the transportation-technological section, the control and shielding system, and the systems for mass control over the technological parameters of the reactor.

On the other hand, the cables crossing areas of intensive radiation must be specially made bearing in mind the influence of radiation on their insulation. As a whole, the power facilities and cables must be made in such a way as to permit their decontamination.

All these characteristics of the electric power system of the AETs are caused by the nature of its technological system and the strict requirements it must meet in terms of operational security and safety.

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INDUSTRIAL WATER SUPPLY AT KOZLODUY NUCLEAR POWER PLANT

Sofia ENERGETIKA in Bulgarian Nos 8-9, Aug-Sep 76 pp 43-45

[Article by Engineer Vasil Naumov, Agrovodkomplekt: "Industrial Water Supply to the Kozloduy AETs [Nuclear Power Plant]"]

[Text] The availability of cooling water is a major prerequisite in the choice of a site for a nuclear electric power plant. In the case of power plants of the Kozloduy AETs type with turbines using low parameter (temperature and pressure) steam the amount of cooling water is approximately twice the required amount for a conventional thermoelectric power plant of the same capacity. This also determines the large size of the industrial water supply equipment for the Kozloduy AETs.

The Energoproekt NIPPIES [Scientific Research Planning and Design Institute for Power Systems] designed the plant's industrial water supply system which, when entirely completed, will deliver 180 m^3/sec--a volume sufficient for the installed 3,000-MW electric power capacity.

Basic Equipment

The basic industrial water supply equipment of the power plant includes the following: a shore pumping station, a cold (supply) canal, a circulation pumping station, and a hot (draining) canal. The hot and cold canals are parallel to each other, and are 6,350 m long each. They are planned to handle the volume of water needed at the final stage--180 m^3/sec--whereas pumping stations are built in stages, in accordance with the planned expansions of the power plants.

Shore Pumping Station

The water is drawn from the Danube River by the shore pumping station built 500 m inland. The canal which links the river with the pumping station insures a water supply even when the Danube River reaches its lowest level. The first stage of the shore pumping station insuring a water supply for a capacity of 880 MW has been completed. Ten vertical axle electric pumping

units have been installed. They are of Soviet manufacture, 110 PR-5 type. Each has a capacity ranging from 5.2 to 6.3 m^3/sec depending on the Danube River level.

The need to make the working pump wheels operate submerged at a depth of no less than 3 m required the sinking of deep foundations for the pumping station averaging 16 m from the surface and 9 m below the lowest river level. The existing geological and hydrogeological conditions--fine river silt and humus at a depth from 2 to 3 m below the surface and, below that, a high filtering level of gravel at a depth of 16 to 18 m, under which was a marl water-confining stratum, made it necessary to line the construction pit in advance with an antifiltration spline screen. The earth removal operations for the screen were carried out with the help of the Italian-made ELSE machine making grooves 500 m long and 0.60 m wide and with a maximal depth of 25 m. In order to prevent crumbling the ditch was kept filled with a bentonite solution at all times. After reaching the water-containing marl within which the wall was to be built at a depth of some 50 cm, the concrete was poured through contracting pipes (with an 18 cm abrams cone pressure) which gradually pushed the bentonite out.

This was the first time that this method for building an antifiltration screen was applied in our country. It was entirely successful. When some of the screen had to be opened and destroyed in the area of the canal linking the river to the already-completed pumping station it was established that the concrete was smooth, with no porosity. The seams between the 5 m intervals were properly processed by the machine and even though the Danube waters were higher than average, i.e., a water pressure in excess of 9 m existed, there was no filtration through the screen.

Despite the existence of a splined wall at the foundations, the water flow reached 180 l/sec and was fed exclusively from the bottom. At some places sandy strata covered by a thin layer of clay pierced by the water under pressure appeared above the marl. Quite probably somewhere the screen may have been left hanging, i.e., it was not drilled into the marl. This called for steady water bailing with several groups of high power pumps.

Supply and Draining Canals and Circulation Pumping Station

From the shore pumping station the water is fed to the so-called cold canal which feeds the circulations pumping station. With the help of eight pumps of the size and type of the shore pumping station the water is pumped to the condensers. There are two pumps per turbogenerator. Also installed in the circulation pumping station are eight artesian pumps for other production requirements as well as two fire-fighting pumps. The stations's foundations are 14 m deep in the area of subsoil waters. The lowering of such waters in laying the foundations was accomplished very carefully in order to avoid the danger of undermining which would have disturbed the stability of the nearby higher foundations of the plant buildings and of the machines. The water reduction was achieved exclusively through a series

of shaped sounding wells equipped with filters. The water pumped out was kept under constant observation. We watched for precipitation or the extraction of fine particles from the soil.

The cold (supply) canal is 19.5 m wide at the bottom. The water layer is 5.10 m deep. The warm (draining) canal has almost identicle dimensions with certain deviations of the width of the bottom in some sectors.

The canals share a common dividing dike. Their bottoms are horizontal. The flow is secured through the hydraulic slant of the water surface. They are lined with a monolithic reinforced concrete slab 20 cm thick on the bottom and 15 cm thick on the sides. The seams (operational each 10 m and expanding each 30 m) have double lining. In laying the concrete, polyvinyl strips, 21 cm wide, were layed precisely in the middle and the area above them was filled with special plastics (thiokol in the most dangerous sectors and sural and bolkit elsewhere).

The reinforced concrete lining for both canals totals 560,000 m^2 and is layed on a 2-layer filter (sand and gravel) 30 cm thick. The concrete laying was totally mechanized with a set of three ABG machines. The first--the concrete spreader--only spread the concrete provided through ZIL dump trucks. The second--the vibration machine--packed the concrete, while the third--the cutter--made the seams with a vibrating cutter. The freshly layed lining was not covered with a mat, which would have required water spraying over 2 weeks, but was sprayed over with a paraffin emulsion. The thick film which formed insured the entirely normal hardening of the concrete.

The building of the systems for industrial water supplying of the first nuclear power plant in Bulgaria is a considerable achievement of our hydro-engineering construction: large scale installations, short deadlines, use of new technologies, and fully mechanized work using modern machinery.

The following main types of work and materials were needed in building the industrial water supply of the Kozluduy AETs:

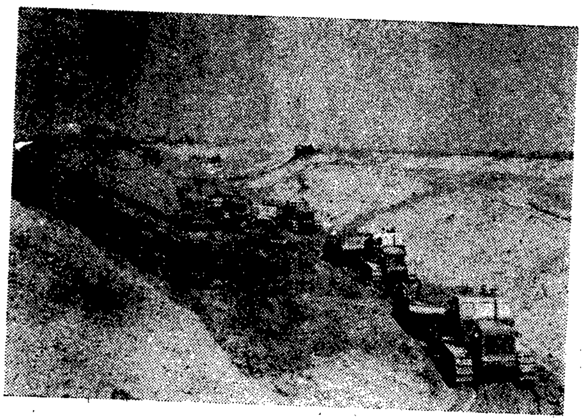
Earth removal work: 8,000,000 m^3
Concrete: 200,000 m^3
Steel: 11,000 tons
Quarry materials: 500,000 m^3
Seams: 80,000 m

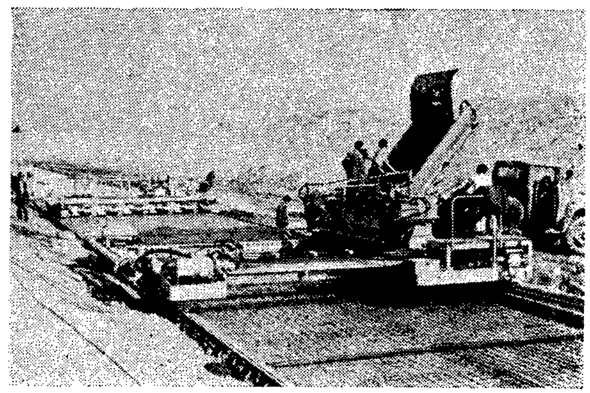
In order for such work to be completed within the 3-year deadline stipulated in the general construction program the tension and pace of the work had to be considerably higher than those so-far reached at other Bulgarian projects. Thus, for example, in building the embankments of the canal which had to be maximally packed with optimal moisture the output reached 28,000 m^3/day and 280,000 m^3/month. Such an output was possible thanks to

the high amount of mechanized facilities. Heavy mechanization machinery used at the project reached a total of 22 cranes, 27 scrapers, 24 bulldozers, 160 dump trucks, 12 rollers, 10 tanker trucks, and others.

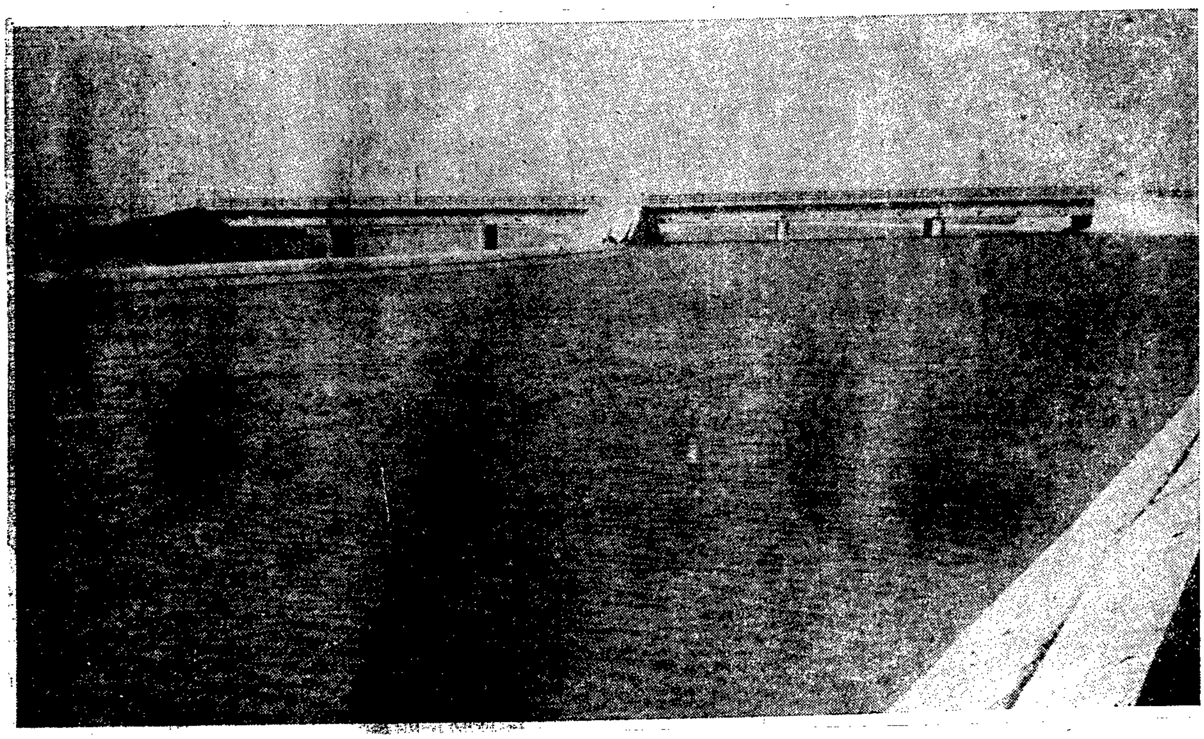
Such extensive mechanization enabled us to increase labor productivity and reach an average annual output in excess of 10,000 leva/person.

The project was completed ahead of schedule despite the high volume. The water required for the tests and for the operations of the power plant began to be supplied on 20 November 1973.





The high mechanization of construction was an important prerequisite for the timely completion of the construction project



The waters of the Danube River lengthened their path near Kozloduy by 14 km along the 2 canals leading to the power plant

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